Oracle® AI Database

JDBC Developer's Guide

26ai
G43022-01
October 2025

Oracle AI Database JDBC Developer's Guide, 26ai

G43022-01

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Preface

This preface introduces you to the intended audience, structure, and conventions of this document. A list of related Oracle documents is also provided.

Audience

The *Oracle Database JDBC Developer's Guide* is intended for developers of Java Database Connectivity (JDBC)-based applications. This book can be read by anyone with an interest in JDBC programming, but assumes at least some prior knowledge of the following:

- Java
- Oracle PL/SQL
- Oracle databases

Related Documents

For more information, see the following documents in the Oracle Database documentation set:

- *Oracle Database Java Developer's Guide*
- *Oracle Database Development Guide*
- *Oracle Database PL/SQL Packages and Types Reference*
- *Oracle Database PL/SQL Language Reference*
- *Oracle Database SQL Language Reference*

You can also find more information on the following pages:

- http://www.oracle.com/technetwork/documentation/index.html
- http://www.oracle.com/technetwork/java/javase/jdbc/index.htm

Conventions

This section describes the conventions used in the text and code examples of this documentation set. It describes:

- Conventions in Text
- Conventions in Code Examples
- Conventions for Windows Operating Systems

Conventions in Text

We use various conventions in text to help you more quickly identify special terms. The following table describes those conventions and provides examples of their use.

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Convention	Meaning
Bold	Bold typeface indicates terms that are defined in the text or terms that appear in a glossary, or both.
Italics	Italic typeface indicates book titles or emphasis.
`UPPERCASE monospace (fixed-width) font`	Uppercase monospace typeface indicates elements supplied by the system. Such elements include parameters, privileges, data types, RMAN keywords, SQL keywords, SQL*Plus or utility commands, packages and methods, as well as system-supplied column names, database objects and structures, user names, and roles.
`lowercase monospace (fixed-width) font`	Lowercase monospace typeface indicates executables, file names, directory names, and sample user-supplied elements. Such elements include computer and database names, net service names, and connect identifiers, as well as user-supplied database objects and structures, column names, packages and classes, user names and roles, program units, and parameter values. **Note:** Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.
`lowercase italic monospace (fixed-width) font`	Lowercase italic monospace font represents placeholders or variables.

Conventions in Code Examples

Code examples illustrate Java, SQL, and command-line statements. Examples are displayed in a monospace (fixed-width) font and separated from normal text as shown in this example:

```
SELECT username FROM dba_users WHERE username = 'MIGRATE';
```

The following table describes typographic conventions used in code examples and provides examples of their use.

Convention	Meaning
`[ ]`	Brackets enclose one or more optional items. Do not enter the brackets.
`{ }`	Braces enclose two or more items, one of which is required. Do not enter the braces.
`|`	A vertical bar represents a choice of two or more options within brackets or braces. Enter one of the options. Do not enter the vertical bar.
`...`	Horizontal ellipsis points indicate either: • That we have omitted parts of the code that are not directly related to the example • That you can repeat a portion of the code
`.` `.` `.`	Vertical ellipsis points indicate that we have omitted several lines of code not directly related to the example.
Other notation	You must enter symbols other than brackets, braces, vertical bars, and ellipsis points as shown.
`Italics`	Italicized text indicates placeholders or variables for which you must supply particular values.
`UPPERCASE`	Uppercase typeface indicates elements supplied by the system. We show these terms in uppercase in order to distinguish them from terms you define. Unless terms appear in brackets, enter them in the order and with the spelling shown. However, because these terms are not case sensitive, you can enter them in lowercase.

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Convention	Meaning
`lowercase`	Lowercase typeface indicates programmatic elements that you supply. For example, lowercase indicates names of tables, columns, or files. **Note:** Some programmatic elements use a mixture of UPPERCASE and lowercase. Enter these elements as shown.

Conventions for Windows Operating Systems

The following table describes conventions for Windows operating systems and provides examples of their use.

Convention	Meaning
Choose Start >	How to start a program.
File and directory names	File and directory names are not case sensitive. The following special characters are not allowed: left angle bracket (<), right angle bracket (>), colon (:), double quotation marks ("), slash (/), pipe (|), and dash (-). The special character backslash (\) is treated as an element separator, even when it appears in quotes. If the file name begins with \\, then Windows assumes it uses the Universal Naming Convention.
`C:\>`	Represents the Windows command prompt of the current hard disk drive. The escape character in a command prompt is the caret (^). Your prompt reflects the subdirectory in which you are working. Referred to as the *command prompt* in this manual.
Special characters	The backslash (\) special character is sometimes required as an escape character for the double quotation mark (") special character at the Windows command prompt. Parentheses and the single quotation mark (') do not require an escape character. Refer to your Windows operating system documentation for more information on escape and special characters.
`HOME_NAME`	Represents the Oracle home name. The home name can be up to 16 alphanumeric characters. The only special character allowed in the home name is the underscore.
`ORACLE_HOME` and *`ORACLE_BASE`*	In releases prior to Oracle8*i* release 8.1.3, when you installed Oracle components, all subdirectories were located under a top level *`ORACLE_HOME`* directory that by default used one of the following names: • `C:\orant` for Windows NT • `C:\orawin98` for Windows 98 This release complies with Optimal Flexible Architecture (OFA) guidelines. All subdirectories are not under a top level *`ORACLE_HOME`* directory. There is a top level directory called *`ORACLE_BASE`* that by default is `C:\oracle`. If you install the latest Oracle release on a computer with no other Oracle software installed, then the default setting for the first Oracle home directory is `C:\oracle\ora`*nn*, where *nn* is the latest release number. The Oracle home directory is located directly under *`ORACLE_BASE`*. All directory path examples in this guide follow OFA conventions. Refer to *Oracle Database Platform Guide for Microsoft Windows* for additional information about OFA compliance and for information about installing Oracle products in non-OFA compliant directories.

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Changes in This Release for Oracle AI Database JDBC Developer's Guide

This section contains the changes in this book for Oracle AI Database Release 26ai.

New Features

This section lists the new features for this release:

> **Note**
>
> For a complete list of Oracle JDBC driver features, refer to the Feature List section.

- Support for Oracle AI Vector Search

  > **See Also**
  >
  > Working with Vectors

- Support for Sessionless Transactions

  > **See Also**
  >
  > Sessionless Transactions

- Support for Jakarta APIs

  > **See Also**
  >
  > Supported JDK and JDBC Versions

- Support for SNI

  > **See Also**
  >
  > SNI Support for TLS Connections

- Support for PEM

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> **See Also**
>
> Support for PEM in JDBC

- Support for Caching SSLContext Instance

> **See Also**
>
> Support for Caching SSLContext Instance

- Support for Fixed Character Semantic

> **See Also**
>
> Support for Fixed Character Semantic

- JDBC Service Provider Extensions

> **See Also**
>
> JDBC Service Provider Extensions

- Enhanced Support for token-based authentication

> **See Also**
>
> Support for Token-Based Authentication for IAM and Support for Token-Based Authentication for Azure AD

- Support for LDAP/LDAPS in the Easy Connect Plus URL

> **See Also**
>
> Support for LDAP and LDAPS

- Support for RADIUS Challenge-Response Authentication

> **See Also**
>
> Support for Challenge-Response Authentication

- Kerberos Authentication Enhancements

> **See Also**
>
> Kerberos Authentication Enhancements

- Support for Kerberos Constrained Delegation

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> **See Also**
>
> Support for Kerberos Constrained Delegation

- Support for Using Alias and Thumbprint of Certificates

> **See Also**
>
> About Managing Certificates and Wallets

- Performance Enhancement of Standard Update Batching

> **See Also**
>
> About Processing the Batch

- Support for Pipelined Database Operations

> **See Also**
>
> Support for Pipelined Database Operations

- Support for Data Load Mode in RSI

> **See Also**
>
> About Reactive Streams Ingestion (RSI) Modes

- Support for Annotations

> **See Also**
>
> Support for Annotations

- Support for Oracle True Cache

> **See Also**
>
> Support for Oracle True Cache

- Support for the Bequeath Protocol

> **See Also**
>
> Support for the Bequeath Protocol

- Support for the SQL `BOOLEAN` Data Type

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> **See Also**
>
> Class oracle.jdbc.OracleTypes and Table of Mappings

- Enhanced, Cloud-Ready Diagnosability Features

> **See Also**
>
> Diagnosability in JDBC

- Support for Multi-Pool DRCP

> **See Also**
>
> Multi-Pool Support in DRCP

- Support for Resumable Cursors with Transparent Application Continuity (TAC)

> **See Also**
>
> Support for Resumable Cursors

- Transaction Guard Support during `DBMS_ROLLING` Operations
  Transaction Guard support for rolling upgrades, using the `DBMS_ROLLING` package, ensures that commit outcomes are guaranteed across the entire upgrade process.

> **See Also**
>
> *Oracle AI Database Development Guide*

- Support for Enqueue and Dequeue of JSON Array Payload Type

> **See Also**
>
> Package oracle.sql.json

- Support for Passwords of Length 1024 Bytes

> **See Also**
>
> Support for Longer Passwords

- Starting from Oracle AI Database Release 26ai, connection pooling support is implicitly provided to JDBC applications that do not use connection pools. So, even if your application does not close a connection explicitly, Database Resident Connection Pool (DRCP) servers are automatically assigned to and from an application connection at run time, when the application initiates and completes database operations.

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> **See Also**
>
> *Oracle AI Database Development Guide*

Deprecated Features

This section lists the deprecated features in this release.

Deprecation of the JDBC OCI Driver

The JDBC OCI Driver or Type 2 Client Driver, is deprecated in Oracle AI Database Release 26ai. Most Java applications that use Open Database Connectivity (ODBC) with Oracle JDBC drivers use the Thin driver. To enable Oracle to allocate resources to better address customer requirements, Oracle is deprecating the JDBC-OCI driver.

Deprecation of Blob, Clob, and BFile Methods

Oracle is deprecating the methods `open()`, `close()`, and `isClosed()` in the interfaces `oracle.jdbc.OracleBlob`, `oracle.jdbc.OracleClob`, and `oracle.jdbc.OracleBfile`.

These methods are replaced with the `openLob()`, `closeLob()` and `isClosedLob()` methods. The method `close()` conflicts with the type `java.lang.AutoCloseable`. Removing the proprietary method `close()` makes it possible for `OracleBlob`, `OracleClob`, and `OracleBfile` interfaces to extend the `AutoCloseable` interface at some future time. The `open()` and `isClosed()` methods will be removed and replaced to maintain rational names for these methods.

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Part I
Overview

The chapters in this part introduce the concept of Java Database Connectivity (JDBC) and provide an overview of the Oracle implementation of JDBC. This part provides basic information about installation and configuration of the Oracle client with reference to JDBC drivers. This part also covers the basic steps in creating and running any JDBC application.

Part I contains the following chapters:

- Introducing JDBC
- Getting Started

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1

Introducing JDBC

Java Database Connectivity (JDBC) is a Java standard that provides the interface for connecting from Java to relational databases. JDBC is based on the X/Open SQL Call Level Interface (CLI). JDBC 4.0 complies with the SQL 2003 standard.

The JDBC standard is defined and implemented through the standard `java.sql` interfaces. This enables individual providers to implement and extend the standard with their own JDBC drivers. This chapter provides an overview of the Oracle implementation of JDBC, covering the following topics:

- Overview of Oracle JDBC Drivers
- Choosing the Appropriate Driver
- Feature Differences Between JDBC OCI and Thin Drivers
- Environments and Support
- Feature List

1.1 Overview of Oracle JDBC Drivers

In addition to supporting the standard JDBC application programming interfaces (APIs), Oracle drivers have extensions to support Oracle-specific data types and to enhance performance.

Oracle provides the following JDBC drivers:

- Thin driver

  The JDBC Thin driver is a pure Java, Type IV driver that can be used in applications. It is platform-independent and does not require any additional Oracle software on the client-side. The JDBC Thin driver communicates with the server using Oracle Net Services to access Oracle Database.

  The JDBC Thin driver enables a direct connection to the database by providing an implementation of Oracle Net Services on top of Java sockets. The driver supports the TCP/IP protocol and requires a TNS listener on the TCP/IP sockets on the database server.

  > **Note**
  >
  > Oracle recommends you to use the Thin driver unless you have a feature that is supported only by a specific driver.

- Oracle Call Interface (OCI) driver

  It is used on the client-side with an Oracle client installation. It can be used only with applications.

  The JDBC OCI driver is a Type II driver used with Java applications. It requires platform-specific OCI libraries. It supports all installed Oracle Net adapters, including interprocess communication (IPC), named pipes, TCP/IP, and Internetwork Packet Exchange/ Sequenced Packet Exchange (IPX/SPX).

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The JDBC OCI driver, written in a combination of Java and C, converts JDBC invocations to calls to OCI, using native methods to call C-entry points. These calls communicate with the database using Oracle Net Services.

The JDBC OCI driver uses the OCI libraries, C-entry points, Oracle Net, core libraries, and other necessary files on the client computer where it is installed.

OCI is an API that enables you to create applications that use the native procedures or function calls of a third-generation language to access Oracle Database and control all phases of the SQL statement processing.

- Server-side Thin driver

  It is functionally similar to the client-side Thin driver. However, it is used for code that runs on the database server and needs to access another session either on the same server or on a remote server on any tier.

  The JDBC server-side Thin driver offers the same functionality as the JDBC Thin driver that runs on the client-side. However, the JDBC server-side Thin driver runs inside Oracle Database and accesses a remote database or a different session on the same database for use with Java in the database.

  This driver is useful in the following scenarios:

  – Accessing a remote database server from an Oracle Database instance acting as a middle tier
  – Accessing an Oracle Database session from inside another, such as from a Java stored procedure

  The use of JDBC Thin driver from a client application or from inside a server does not affect the code.

- Server-side internal driver

  It is used for code that runs on the database server and accesses the same session. That is, the code runs and accesses data from a single Oracle session.

  The JDBC server-side internal driver supports any Java code that runs inside Oracle Database, such as in a Java stored procedure, and accesses the same database. It lets the Oracle Java Virtual Machine (Oracle JVM) to communicate directly with the SQL engine for use with Java in the database.

  The JDBC server-side internal driver, the Oracle JVM, the database, and the SQL engine all run within the same address space, and therefore, the issue of network round-trips is irrelevant. The programs access the SQL engine by using function calls.

  > **Note**
  >
  > The server-side internal driver does not support the `cancel` and `setQueryTimeout` methods of the `Statement` class.

  The JDBC server-side internal driver is fully consistent with the client-side drivers and supports the same features and extensions.

The following figure illustrates the architecture of Oracle JDBC drivers and Oracle Database.

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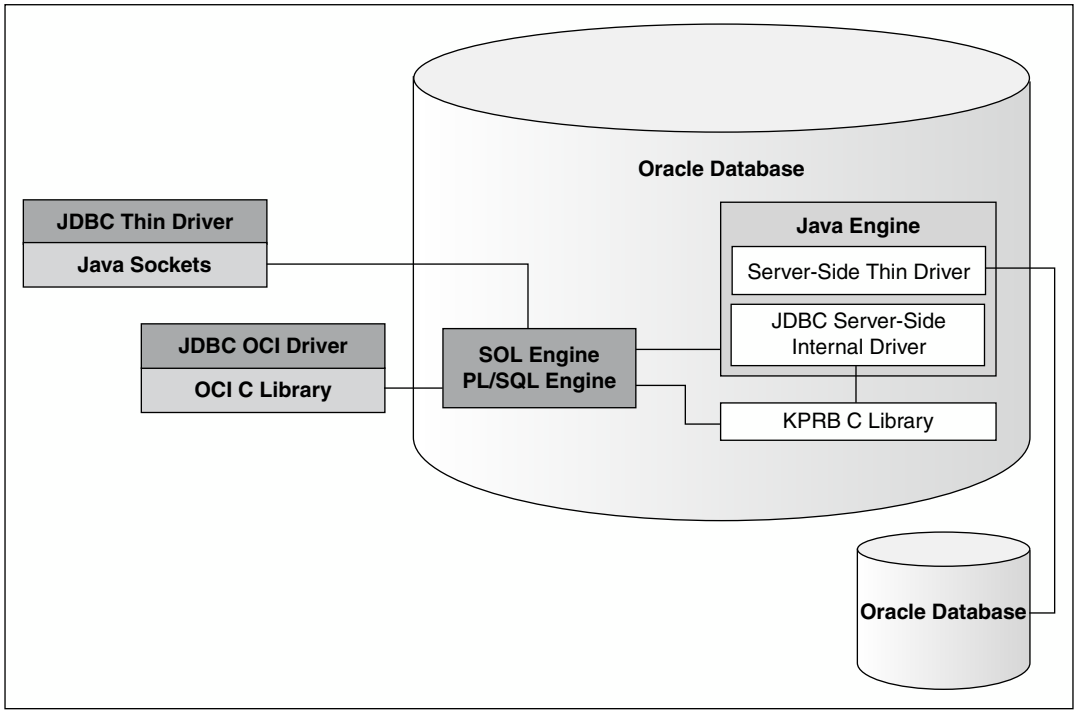
Figure 1-1 Architecture of Oracle JDBC Drivers and Oracle Database



Related Topics

- Features Specific to JDBC Thin
- Features Specific to JDBC OCI Driver
- Server-Side Internal Driver

1.2 Choosing the Appropriate Driver

Consider the following when choosing a JDBC driver for your application or applet:

- In general, unless you need OCI-specific features, such as support for non-TCP/IP networks, use the JDBC Thin driver.
- If you want maximum portability and performance, then use the JDBC Thin driver. You can connect to Oracle Database from an application using the JDBC Thin driver.
- If you want to use Lightweight Directory Access Protocol (LDAP) over Transport Layer Security (TLS), then use the JDBC Thin driver.
- If you are writing a client application for an Oracle client environment and need OCI-driver-specific features, such as support for non-TCP/IP networks, then use the JDBC OCI driver.
- For code that runs in the database server and needs to access a remote database or another session within the same database instance, use the JDBC server-side Thin driver.
- If your code runs inside the database server and needs to access data locally within the session, then use the JDBC server-side internal driver to access that server.

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1.3 Use Cases of Oracle JDBC Drivers

This section describes the use cases for Oracle JDBC drivers.

JDBC Thin Driver or Type 4 Client Driver

You must use the JDBC Thin driver in your client-side Java applications for accessing Oracle Database over the TCP/IP protocol, for both `tcp` and `tcps`. This is the most widely used driver that Oracle recommends to use because it offers a range of features as mentioned in the following non-exhaustive list:

- Row count per iteration
- Support for promoting a local transaction to a global transaction
- Transaction Guard
- Transparent Application Continuity and Application Continuity
- Support for the Reactive Streams Ingestion library
- JDBC Reactive Extensions

> **See Also**
>
> Feature List

JDBC OCI Driver or Type 2 Client Driver

You must use the JDBC OCI driver in your client-side Java applications only if your applications use any of the following features that are dependent on the platform-specific OCI libraries:

- Bequeath protocol
  This procol lets you use the local connections without going through the listener, which is typically used by the Database Administrators to perform various administrative operations; however, other non-administrative users too can use this protocol.

  > **See Also**
  >
  > Using Bequeath Connection and SYS Logon

- OS Authentication
  The JDBC OCI driver supports OS Authentication on Linux when the client and the server are on the same computer. On Window domains, it supports OS Authentication even across multiple computers.
- Transparent Application Failover (TAF) that supports failover of read transactions.

  > **See Also**
  >
  > Application Continuity for Java for information about complete high availability features

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Server-Side Internal Driver or Type 2 Server-Side Driver

You must use this driver for Java code that runs on the JVM embedded in the Database server and accesses the same Database session. It means that the code runs and accesses data from a single Database session. This driver is also known as the JDBC KPRB Driver.

This driver is built in the JVM embedded in the Database, also known as Oracle JVM, and it is not a fully-featured driver.

Server-Side Thin Driver or Type 4 Server-Side Driver

You must use this driver in the following scenarios:

- For accessing a remote database server from an Oracle Database instance acting as a middle tier
- For accessing an Oracle Database session from within another session, such as from a Java stored procedure

This driver is built in the Oracle JVM, and it is not a fully-featured driver.

1.4 Feature Differences Between JDBC OCI and Thin Drivers

The following table lists the features that are specific either to the JDBC OCI or the JDBC Thin driver in Oracle AI Database Release 26ai.

Table 1-1 Feature Differences Between the JDBC OCI Driver and the JDBC Thin Driver

JDBC OCI Driver	JDBC Thin Driver
OCI connection pooling	NA
Transparent Application Failover (TAF)	NA
NA	Support for row count per iteration for array DML
NA	SHA-2 Support in Oracle Advanced Security
`oraaccess.xml` configuration file settings	NA
NA	Oracle Advanced Queuing
NA	Support for the `07L_MR` client ability
NA	Support for promoting a local transaction to a global transaction
NA	Java Data Source for Sharded Databases Access
NA	Java Library for Reactive Streams Ingestion
NA	JDBC Reactive Extensions
NA	Native JSON Type Support

Note

- The OCI optimized fetch feature is internal to the JDBC OCI driver and not applicable to the JDBC Thin driver.
- Some JDBC OCI driver features, inherited from the OCI library, are not available in the Thin JDBC driver.

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1.5 Environments and Support

This section provides a brief description of the tools and environments that you need to run a JDBC application.

- Supported JDK and JDBC Versions
- JNI and Java Environments
- JDBC and IDEs
- Availability on Maven Central

1.5.1 Supported JDK and JDBC Versions

In Oracle AI Database 26ai, all the JDBC drivers are compatible with JDK 8, JDK 11, and JDK 17, and the `ojdbc8.jar`, `ojdbc11.jar`, and `ojdbc17.jar` files provide the support to these JDK versions.

When to Use ojdbc8.jar File

Use the `ojdbc8.jar` file when you want JDBC 4.2 features and need to compile your code with JDK 8 and JDK 11.

When to Use ojdbc11.jar File

Use the `ojdbc11.jar` file when you want JDBC 4.3 features and need to compile your code with JDK 11.

> **See Also**
>
> JDBC FAQ Page

When to Use ojdbc17.jar File

Use the `ojdbc17.jar` file when you want JDBC 4.3 features and need to compile your code with JDK 17 and above. This JAR file is compatible with the Jakarta APIs.

Related Topics

- RDBMS and JDK Version Compatibility for Oracle JDBC Drivers
  Oracle AI Database Release 26ai JDBC drivers are certified with all the supported Oracle Database releases (26ai, 21c, and 19c).

1.5.2 JNI and Java Environments

The JDBC OCI driver uses the standard Java Native Interface (JNI) to call OCI C libraries. You can use the JDBC OCI driver with Java Virtual Machines (JVMs), in particular, with Microsoft and IBM JVMs.

1.5.3 JDBC and IDEs

The Oracle JDeveloper Suite provides developers with a single, integrated set of products to build, debug, and deploy component-based database applications for the Internet. The Oracle

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JDeveloper environment contains integrated support for JDBC, including the JDBC Thin driver and the native OCI driver. The database component of Oracle JDeveloper uses the JDBC drivers to manage the connection between the application running on the client and the server.

1.5.4 Availability on Maven Central

All supported releases of the Oracle JDBC drivers, including 21.1.0.0, 19.9.0.0, 19.8.0.0, 19.6.0.0, 19.3.0.0, and 18.3.0.0, are available on Maven Central. So, you can consider Maven Central as a distribution center for the Oracle JDBC drivers and companion JAR files.

Group IDs for JDBC Drivers and Companion JAR Files on Maven Central

All Oracle Database artifacts on Maven Central reside under the same umbrella `com.oracle.database` as shown in the following image:

You can find the Oracle Database Artifacts under their specific focus area. For example, JDBC, XML, security, high-availability (HA), NLS, observability, and so on. The following table lists the group IDs of the JDBC drivers and the companion JAR files:

Group ID	Corresponding JAR Files
`com.oracle.database.jdbc`	`ojdbc11.jar`, `ojdbc10.jar`, `ojdbc8.jar`, `ojdbc6.jar`, `ojdbc5.jar`, `ucp.jar`, `ojdbc10dms.jar`, `ojdbc8dms.jar`, `ojdbc6dms.jar`, `ojdbcd5dms.jar`
`com.oracle.database.jdbc.debug`	`ojdbc11_g.jar`, `ojdbc10_g.jar`, `ojdbc8_g.jar`, `ojdbc6_g.jar`, `ojdbc5_g.jar`, `ojdbc11dms_g.jar`, `ojdbc10dms_g.jar`, `ojdbc8dms_g.jar`, `ojdbc6dms_g.jar`, `ojdbc5dms_g.jar`
`com.oracle.database.security`	`oraclepki.jar`
`com.oracle.database.ha`	`ons.jar`, `simplefan.jar`
`com.oracle.database.nls`	`orai18n.jar`

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Group ID	Corresponding JAR Files
com.oracle.database.xml	xdb.jar, xdb6.jar, xmlparserv2.jar
com.oracle.database.observability	dms.jar

Note

- The ojdbc8dms.jar and ojdbc11dms.jar files provide complete support for the Dynamic Monitoring System (DMS) and limited support for the java.util.logging package.
- xdb6.jar is a legacy name. The new name is xdb.jar.

Managing Dependencies on Maven Central with GAVs

You can manage the JDBC and UCP dependencies in the pom.xml file of your project by using the corresponding group ID, artifact ID, and the version (GAV), as defined in this section. For example, the following GAV pulls the ojdbc10.jar, ucp.jar, oraclepki.jar, ons.jar, and simplefan.jar from the 19.3 release:

```
<dependency>
      <groupId>com.oracle.database.jdbc</groupId>
      <artifactId>ojdbc10</artifactId>
      <version>19.3.0.0</version>
    </dependency>
```

Similarly, the following GAV pulls the orai18n.jar file from the 19.3.0.0 release:

```
<dependency>
      <groupId>com.oracle.database.nls</groupId>
      <artifactId>orai18n</artifactId>
      <version>19.3.0.0</version>
    </dependency>
```

See Also

JDBC FAQ Page

1.6 Feature List

This section lists the supported features and the corresponding versions in which they were first supported in the JDBC OCI driver and the JDBC Thin driver.

Table 1-2 Feature List

Feature	JDBC OCI	JDBC Thin
TimeZone Patching	11.2	11.2
Secure LOB Support	11.2	11.2

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Table 1-2 (Cont.) Feature List

Feature	JDBC OCI	JDBC Thin
LOB prefetch Support	11.2	11.2
Network Connection Pool	NA	11.2
Column Security Support	NA	11.2
XMLType Queue Support (AQ)	NA	11.2
Notification Grouping (AQ and DCN)	NA	11.2
SimpleFAN	11.2	11.2
Application Continuity	12.2	12.1
Transaction Guard	12.2	12.1
SQL Statement Translation	NA	12.1
Database Resident Connection Pooling	12.1	12.1
SHA-2 Support in Oracle Advanced Security	NA	12.1
Invisible Columns Support	12.1	12.1
Support for PL/SQL Package Types as Parameters	12.1	12.1
Support for Monitoring of Database Operations	12.1	12.1
Support for Increased Length Limit for Various Data Types	12.1	12.1
Implicit Results Support	12.1	12.1
Support for row count per iteration for array DML	NA	12.1
`oraaccess.xml` configuration file settings	12.1	NA
Transparent Application Continuity	NA	18c
Support for verifying JSON Data	18c	18c
Support for Lightweight Connection Validation	NA	18c
Support for REF CURSOR as IN bind variables	18c	18c
Support for Key Store Service	NA	18c
Easy Connect Plus (Easy Connect Naming Syntax Improvements)	NA	19c
Token-Based Authentication for IAM	NA	19c
Token-Based Authentication for Azure AD	NA	19c
Java Library for Reactive Streams Ingestion	NA	21c
Java Data Source for Sharded Databases Access	NA	21c
JDBC Support for Native JSON Data Type	NA	21c
JDBC Reactive Extensions	NA	21c
Java Virtual Threads	NA	21c
JDBC Pipelining Support	26ai	26ai
JDBC Service Provider Extensions	NA	26ai
Self-Driven Diagnosability	NA	26ai
Kerberos Constrained Delegation	NA	26ai
RADIUS Challenge-Response Authentication	NA	26ai
True Cache Data Source	26ai	26ai
Data Load Mode in RSI	NA	26ai
Bequeath Protocol	NA	26ai
Resumable Cursors	NA	26ai
Multiple Pool in DRCP	26ai	26ai

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Note

- The following features of JDBC drivers were introduced in releases earlier than release 11.2:
  - NLS Support
  - New Statement Caching API
  - Row Prefetch
  - Java Native Interface
  - Native LOB
  - Associative Arrays/index-by-table
  - Implicit Statement Caching
  - Explicit Statement Caching
  - Temporary LOBs
  - Object Type Inheritance
  - Multilevel Collections
  - `oracle.jdbc` Interfaces
  - Native XA
  - OCI Connection Pooling
  - Transparent Application Failover
  - Implicit Connection Cache
  - Fast Connection Failover
  - Connection Wrapping
  - DMS
  - Service Names in URLs
  - Set Statement Parameters by Name
  - End-to-End Tracing
  - Web `RowSet`
  - Proxy Authentication
  - Run-time Connection Load Balancing
  - Extended `setXXX` and `getXXX` methods for LOBs
  - XA Connection Cache
  - DML Returning
  - JSR 114 `RowSets`
  - SSL/TLS Encryption
  - SSL/TLS Authentication
  - AES Encryption
  - SHA1 Hash
  - Radius Authentication

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  - Kerberos Authentication
  - `ANYDATA` and `ANYTYPE` types
  - Native AQ
  - Query Change Notification
  - Database start up and shut down
  - Factory methods for data types
  - Buffer Cache
  - Secure File LOBs
  - Diagnosability
  - Server Result Cache
  - Universal Connection Pool
- The `ConnectionCacheImpl` connection cache feature is deprecated since Oracle Database 10*g*.
- The Implicit Connection Cache feature is desupported now.

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2

Getting Started

This chapter discusses the compatibility of Oracle Java Database Connectivity (JDBC) driver versions, database versions, and Java Development Kit (JDK) versions.

It also describes the basics of testing a client installation and configuration and running a simple application. This chapter contains the following sections:

- Version Compatibility for Oracle JDBC Drivers
- Verifying a JDBC Client Installation
- Basic Steps in JDBC
- Sample: Connecting_ Querying_ and Processing the Results
- Support for JSON-Relational Duality Views
- Support for Fixed Character Semantic
- Support for Java Virtual Threads
- Support for Annotations
- Support for Oracle True Cache
- Support for the Bequeath Protocol
- Support for Invisible Columns
- Support for Verifying JSON Data
- Support for Implicit Results
- Support for Lightweight Connection Validation
- Support for Deprioritization of Database Nodes
- Support for Oracle Connection Manager in Traffic Director Mode
- Stored Procedure Calls in JDBC Programs
- About Processing SQL Exceptions

2.1 RDBMS and JDK Version Compatibility for Oracle JDBC Drivers

Oracle AI Database Release 26ai JDBC drivers are certified with all the supported Oracle Database releases (26ai, 21c, and 19c).

The following table describes the JDBC and Oracle Database interoperability matrix or the certification matrix:

JDBC Driver Version	Database 26.x	Database 21.x	Database 19.x
JDBC 26	Yes	Yes	Yes
JDBC 21.x	Yes	Yes	Yes
JDBC 19.x	Yes	Yes	Yes

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Oracle JDBC Drivers are always compliant to the latest JDK version for every new release. For some versions, JDBC drivers support multiple JDK versions. The following table describes the release-specific JDBC JAR files and supported JDK versions for various Oracle Database versions:

> **Note**
>
> `ojdbc8.jar` support with JDK 11, JDK 17, and JDK 19 is limited only to the JDBC 4.2 APIs because `ojdbc8.jar` does not support JDBC 4.3 APIs.

Oracle JDBC Version	Release-Specific JDBC JAR File with Supported JDK Versions
26.x	`ojdbc17.jar` JDK 17, JDK 19, and JDK 21 `ojdbc11.jar` with JDK 11 `ojdbc8.jar` with JDK 8 and JDK 11
21.x	`ojdbc11.jar` with JDK 11, JDK 17, and JDK 19 `ojdbc8.jar` with JDK 8 and JDK 11
19.x	`ojdbc10.jar` with JDK 11 and JDK 17 `ojdbc8.jar` with JDK 8, JDK 11, JDK 17, and JDK 19

Related Topics

- *Oracle Universal Connection Pool Developer's Guide*
- Oracle JDBC FAQ

2.2 Verifying a JDBC Client Installation

This section describes the steps that you must perform to verify a JDBC client installation.

- Checking the Environment Variables
- Ensuring that the Java Code Can Be Compiled and Run
- Determining the Version of the JDBC Driver
- Testing the JDBC and Database Connection

> **Note**
>
> - If you use the JDBC Thin driver, then there is no additional installation on the client computer. If you use the JDBC Oracle Call Interface (OCI) driver, then you must also install the Oracle client software. This includes Oracle Net and the OCI libraries.
> - The JDBC Thin driver requires a TCP/IP listener to be running on the computer, where the database is installed.

This section describes the steps for verifying an Oracle client installation of the JDBC drivers, assuming that you have already installed the driver of your choice. Installation of an Oracle JDBC driver is platform-specific. You must follow the installation instructions for the driver you want to install in your platform-specific documentation.

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2.2.1 Checking the Environment Variables

This section describes the environment variables that you must set for the JDBC OCI driver and the JDBC Thin driver, focusing on Solaris, Linux, and Microsoft Windows platforms.

JDBC Thin Driver

You must set the `CLASSPATH` environment variable for using the JDBC Thin driver, in a way similar to the following:

```
jdbc/lib/ojdbc11.jar
jlib/orai18n.jar
```

> **Note**
>
> If you use the JTA features and the JNDI features, then you must specify `jta.jar` and `jndi.jar` in your `CLASSPATH` environment variable.

JDBC OCI Driver

You must set the `CLASSPATH` environment variable for using the JDBC OCI driver, in a way similar to the following:

```
ORACLE_HOME/jdbc/lib/ojdbc11.jar
ORACLE_HOME/jlib/orai18n.jar
```

> **Note**
>
> If you use the JTA features and the JNDI features, then you must specify `jta.jar` and `jndi.jar` in your `CLASSPATH` environment variable.

To use the JDBC OCI driver, you must also set the value for the library path environment variable in a way similar to the following:

- On Solaris or Linux, set the `LD_LIBRARY_PATH` environment variable as follows:

  ```
  ORACLE_HOME/lib
  ```

  This directory contains the `libocijdbc11.so` shared object library.
- On Microsoft Windows, set the `PATH` environment variable as follows:

  ```
  ORACLE_HOME\bin
  ```

  This directory contains the `ocijdbc11.dll` dynamic link library.

All of the JDBC OCI demonstration programs can be run in the Instant Client mode by including the JDBC OCI Instant Client data shared library on the library path environment variable.

Setting Permission for the Server-Side Thin Driver

To use the JDBC server-side Thin driver, you must set permissions because the JDBC server-side Thin driver opens a socket for its connection to the database. So, Oracle Database enforces the Java security model and performs a check for a `SocketPermission` object.

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The following is an example of how the permission can be granted for the user HR:

```
CREATE ROLE jdbcthin;
CALL dbms_java.grant_permission('JDBCTHIN', 'java.net.SocketPermission', '*', 'connect');
GRANT jdbcthin TO HR;
```

Note that JDBCTHIN in the grant_permission call must be in uppercase. The asterisk (*) is a pattern. You can restrict the user by granting permission to connect to only specific computers or ports.

Related Topics

- Features Specific to JDBC OCI Driver
- *Oracle AI Database Java Developer's Guide*

2.2.2 Ensuring that the Java Code Can Be Compiled and Run

To further ensure that Java is set up properly on your client system, go to the samples directory under the *ORACLE_HOME*/jdbc/demo directory. Now, type the following commands on the command line, one after the other, to see if the Java compiler and the Java interpreter run without error:

```
javac

java
```

Each of the preceding commands should display a list of options and parameters and then exit. Ideally, verify that you can compile and run a simple test program, such as jdbc/demo/samples/generic/SelectExample.

2.2.3 Determining the Version of the JDBC Driver

It is very important to use the correct version of the JDBC driver in your applications.

Use the following commands to determine the version of the JDBC driver:

- java -jar ojdbc8.jar
- java -jar ojdbc11.jar
- java -jar ojdbc17.jar

You can also call the getDriverVersion method of the OracleDatabaseMetaData class, as shown in the following sample code:

```
import java.sql.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.OracleDataSource;

class JDBCVersion
{
  public static void main (String args[]) throws SQLException
  {
    OracleDataSource ods = new OracleDataSource();
    ods.setURL("jdbc:oracle:thin:HR/<password>@<host>:<port>:<service>");
    Connection conn = ods.getConnection();

    // Create Oracle DatabaseMetaData object
    DatabaseMetaData meta = conn.getMetaData();

    // gets driver info:
```


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```
    System.out.println("JDBC driver version is " + meta.getDriverVersion());
  }
}
```

2.2.4 Testing the JDBC and Database Connection

The `samples` directory contains sample programs for a particular Oracle JDBC driver. One of the programs, `JdbcCheckup.java`, is designed to test JDBC and the database connection. The program queries for the user name, password, and the name of the database to which you want to connect. The program connects to the database, queries for the string "`Hello World`", and prints it to the screen.

Go to the `samples` directory, and compile and run the `JdbcCheckup.java` program. If the results of the query print without error, then your Java and JDBC installations are correct.

Although `JdbcCheckup.java` is a simple program, it demonstrates several important functions by performing the following:

- Imports the necessary Java classes, including JDBC classes
- Creates a `DataSource` instance
- Connects to the database
- Runs a simple query
- Prints the query results to your screen

The `JdbcCheckup.java` program, which uses the JDBC OCI driver, is as follows:

```
/*
 * This sample can be used to check the JDBC installation.
 * Just run it and provide the connect information. It will select
 * "Hello World" from the database.
 */

// You need to import the java.sql and JDBC packages to use JDBC
import java.sql.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.OracleDataSource;

// We import java.io to be able to read from the command line
import java.io.*;

class JdbcCheckup
{
  public static void main(String args[]) throws SQLException, IOException
  {

    // Prompt the user for connect information
    System.out.println("Please enter information to test connection to
                        the database");
    String user;
    String password;
    String database;

    user = readEntry("user: ");
    int slash_index = user.indexOf('/');
    if (slash_index != -1)
    {
      password = user.substring(slash_index + 1);
      user = user.substring(0, slash_index);
    }
```


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```
    else
      password = readEntry("password: ");
    database = readEntry("database(a TNSNAME entry): ");

    System.out.print("Connecting to the database...");
    System.out.flush();
    System.out.println("Connecting...");
    // Open an OracleDataSource and get a connection
    OracleDataSource ods = new OracleDataSource();
    ods.setURL("jdbc:oracle:oci:@" + database);
    ods.setUser(user);
    ods.setPassword(password);
    Connection conn = ods.getConnection();
    System.out.println("connected.");

    // Create a statement
    Statement stmt = conn.createStatement();

    // Do the SQL "Hello World" thing
    ResultSet rset = stmt.executeQuery("select 'Hello World' from dual");

    while (rset.next())
      System.out.println(rset.getString(1));
    // close the result set, the statement and the connection
    rset.close();
    stmt.close();
    conn.close();
    System.out.println("Your JDBC installation is correct.");
  }

  // Utility function to read a line from standard input
  static String readEntry(String prompt)
  {
    try
    {
      StringBuffer buffer = new StringBuffer();
      System.out.print(prompt);
      System.out.flush();
      int c = System.in.read();
      while (c != '\n' && c != -1)
      {
        buffer.append((char)c);
        c = System.in.read();
      }
      return buffer.toString().trim();
    }
    catch(IOException e)
    {
      return "";
    }
  }
}
```

2.3 Basic Steps in JDBC

After verifying the JDBC client installation, you can start creating your JDBC applications. When using Oracle JDBC drivers, you must include certain driver-specific information in your programs. This section describes, in the form of a tutorial, where and how to add the information. The tutorial guides you through the steps to create code that connects to and queries a database from the client.

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You must write code to perform the following tasks:

1. Importing Packages
2. Opening a Connection to a Database
3. Creating a Statement Object
4. Running a Query and Retrieving a Result Set Object
5. Processing the Result Set Object
6. Closing the Result Set and Statement Objects
7. Making Changes to the Database
8. About Committing Changes
9. Closing the Connection

> **Note**
>
> You must supply Oracle driver-specific information for the first three tasks that enable your program to use the JDBC application programming interface (API) to access a database. For the other tasks, you can use standard JDBC Java code, as you would for any Java application.

2.3.1 Importing Packages

Regardless of which Oracle JDBC driver you use, include the `import` statements shown in Table 2-1 at the beginning of your program using the following syntax:

```
import <package_name>;
```

Table 2-1 Import Statements for JDBC Driver

Import statement	Provides
`import java.sql.*;`	Standard JDBC packages.
`import java.math.*;`	The `BigDecimal` and `BigInteger` classes. You can omit this package if you are not going to use these classes in your application.
`import oracle.jdbc.*;`	Oracle extensions to JDBC. This is optional.
`import oracle.jdbc.pool.*;`	`OracleDataSource`.
`import oracle.sql.*;`	Oracle type extensions. This is optional.

The Oracle packages listed as optional provide access to the extended functionality provided by Oracle JDBC drivers, but are not required for the example presented in this section.

> **Note**
>
> It is better to import only the classes your application needs, rather than using the wildcard asterisk (*). This guide uses the asterisk (*) for simplicity, but this is not the recommended way of importing classes and interfaces.

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2.3.2 Opening a Connection to a Database

First, you must create an `OracleDataSource` instance. Then, open a connection to the database using the `OracleDataSource.getConnection` method. The properties of the retrieved connection are derived from the `OracleDataSource` instance. If you set the URL connection property, then all other properties, including `TNSEntryName`, `DatabaseName`, `ServiceName`, `ServerName`, `PortNumber`, `Network Protocol`, and driver type are ignored.

Specifying a Database URL, User Name, and Password

The following code sets the URL, user name, and password for a data source:

```
OracleDataSource ods = new OracleDataSource();
ods.setURL(url);
ods.setUser(user);
ods.setPassword(password);
```

The following example connects user `HR` with password `hr` to a database with service `orcl` through port 5221 of the host `myhost`, using the JDBC Thin driver:

```
OracleDataSource ods = new OracleDataSource();
String url = "jdbc:oracle:thin:@myhost:5221/orcl";
ods.setURL(url);
ods.setUser("HR");
ods.setPassword("hr");
Connection conn = ods.getConnection();
```

> **Note**
>
> The user name and password specified in the arguments override any user name and password specified in the URL.

Specifying a Database URL that Includes User Name and Password

The following example connects user `HR` with password `hr` to a database host whose Transparent Network Substrate (TNS) entry is `myTNSEntry`, using the JDBC Oracle Call Interface (OCI) driver. In this case, the URL includes the user name and password and is the only input parameter.

```
String url = "jdbc:oracle:oci:HR/<password>@myTNSEntry");
ods.setURL(url);
Connection conn = ods.getConnection();
```

If you want to connect using the Thin driver, then you must specify the port number. For example, if you want to connect to the database on the host `myhost` that has a TCP/IP listener on port 5221 and the service identifier is `orcl`, then provide the following code:

```
String URL = "jdbc:oracle:thin:HR/<password>@myhost:5221/orcl");
ods.setURL(URL);
Connection conn = ods.getConnection();
```

Related Topics

- Data Sources and URLs
- Data Sources and URLs

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2.3.3 Creating a Statement Object

Once you connect to the database and, in the process, create a `Connection` object, the next step is to create a `Statement` object. The `createStatement` method of the JDBC `Connection` object returns an object of the JDBC `Statement` type. To continue the example from the previous section, where the `Connection` object `conn` was created, here is an example of how to create the `Statement` object:

```
Statement stmt = conn.createStatement();
```

2.3.4 Running a Query and Retrieving a Result Set Object

To query the database, use the `executeQuery` method of the `Statement` object. This method takes a SQL statement as input and returns a JDBC `ResultSet` object.

> **Note**
>
> - The method used to execute a `Statement` object depends on the type of SQL statement being executed. If the `Statement` object represents a SQL query returning a `ResultSet` object, the `executeQuery` method should be used. If the SQL is known to be a DDL statement or a DML statement returning an update count, the `executeUpdate` method should be used. If the type of the SQL statement is not known, the `execute` method should be used.
> - In case of a standard JDBC driver, if the SQL string being executed does not return a `ResultSet` object, then the `executeQuery` method throws a `SQLException` exception. In case of an Oracle JDBC driver, the `executeQuery` method does not throw a `SQLException` exception even if the SQL string being executed does not return a `ResultSet` object.

To continue the example, once you create the `Statement` object `stmt`, the next step is to run a query that returns a `ResultSet` object with the contents of the `first_name` column of a table of employees named `EMPLOYEES`:

```
ResultSet rset = stmt.executeQuery ("SELECT first_name FROM employees");
```

2.3.5 Processing the Result Set Object

Once you run your query, use the `next()` method of the `ResultSet` object to iterate through the results. This method steps through the result set row by row, detecting the end of the result set when it is reached.

To pull data out of the result set as you iterate through it, use the appropriate `get`*`XXX`* methods of the `ResultSet` object, where *`XXX`* corresponds to a Java data type.

For example, the following code will iterate through the `ResultSet` object, `rset`, from the previous section and will retrieve and print each employee name:

```
while (rset.next())
   System.out.println (rset.getString(1));
```

The `next()` method returns `false` when it reaches the end of the result set. The employee names are materialized as Java `String` values.

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2.3.6 Closing the Result Set and Statement Objects

You must explicitly close the `ResultSet` and `Statement` objects after you finish using them. This applies to all `ResultSet` and `Statement` objects you create when using Oracle JDBC drivers. The drivers do not have finalizer methods. The cleanup routines are performed by the `close` method of the `ResultSet` and `Statement` classes. If you do not explicitly close the `ResultSet` and `Statement` objects, serious memory leaks could occur. You could also run out of cursors in the database. Closing both the result set and the statement releases the corresponding cursor in the database. If you close only the result set, then the cursor is not released.

For example, if your `ResultSet` object is `rset` and your `Statement` object is `stmt`, then close the result set and statement with the following lines of code:

```
rset.close();
stmt.close();
```

When you close a `Statement` object that a given `Connection` object creates, the connection itself remains open.

> **Note**
>
> Typically, you should put `close` statements in a `finally` clause.

2.3.7 Making Changes to the Database

DML Operations

To perform DML (Data Manipulation Language) operations, such as INSERT or UPDATE operations, you can create either a `Statement` object or a `PreparedStatement` object. `PreparedStatement` objects enable you to run a statement with varying sets of input parameters. The `prepareStatement` method of the JDBC `Connection` object lets you define a statement that takes variable bind parameters and returns a JDBC `PreparedStatement` object with your statement definition.

Use the `set`*`XXX`* methods on the `PreparedStatement` object to bind data to the prepared statement to be sent to the database.

The following example shows how to use a prepared statement to run `INSERT` operations that add two rows to the `EMPLOYEES` table.

```
    // Prepare to insert new names in the EMPLOYEES table
PreparedStatement pstmt = null;
try{
    pstmt = conn.prepareStatement ("insert into EMPLOYEES (EMPLOYEE_ID, FIRST_NAME)
values (?, ?)");

    // Add LESLIE as employee number 1500
    pstmt.setInt (1, 1500);          // The first ? is for EMPLOYEE_ID
    pstmt.setString (2, "LESLIE");   // The second ? is for FIRST_NAME
    // Do the insertion
    pstmt.execute();

    // Add MARSHA as employee number 507
    pstmt.setInt (1, 507);           // The first ? is for EMPLOYEE_ID
```


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```
    pstmt.setString (2, "MARSHA");   // The second ? is for FIRST_NAME
    // Do the insertion
    pstmt.execute();
}

finally{
        if(pstmt!=null)

    // Close the statement
    pstmt.close();
}
```

DDL Operations

To perform data definition language (DDL) operations, you must create a `Statement` object. The following example shows how to create a table in the database:

```
//create table EMPLOYEES with columns EMPLOYEE_ID and FIRST_NAME
String query;
Statement stmt=null;

try{
    query="create table EMPLOYEES " +
          "(EMPLOYEE_ID int, " +
          "FIRST_NAME varchar(50))";
    stmt = conn.createStatement();
    stmt.executeUpdate(query);
    }
finally{
     //close the Statement object
     stmt.close();
    }
```

> **Note**
>
> You can also use a `PreparedStatement` object to perform DDL operations. However, you should not use a `PreparedStatement` object because the useful part of such an object is that it can have parameters and a DDL operation does not have any parameters.
>
> Also, due to a Database limitation, if you use a `PreparedStatement` object for a DDL operation, then it only works for the first time it is executed. So, you should use only `Statement` objects for DDL operations.

The following example shows how to prepare your DDL statements before any reexecution:

```
//
Statement stmt = null;
PreparedStatement pstmt = null;
try{
    pstmt = conn.prepareStatement ("insert into EMPLOYEES (EMPLOYEE_ID, FIRST_NAME)
values (?, ?)");
    stmt = conn.createStatement("truncate table EMPLOYEES");

    // Add LESLIE as employee number 1500
    pstmt.setInt (1, 1500);          // The first ? is for EMPLOYEE_ID
    pstmt.setString (2, "LESLIE");   // The second ? is for FIRST_NAME
    pstmt.execute();
    stmt.executeUpdate();
```


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```
    // Add MARSHA as employee number 507
    pstmt.setInt (1, 507);           // The first ? is for EMPLOYEE_ID
    pstmt.setString (2, "MARSHA");   // The second ? is for FIRST_NAME
    pstmt.execute();
    stmt.executeUpdate();
    }
finally{
if(pstmt!=null)

    // Close the statement
     pstmt.close();
}
```

Related Topics

- The setObject and setOracleObject Methods
- Other setXXX Methods

2.3.8 About Committing Changes

By default, data manipulation language (DML) operations are committed automatically as soon as they are run. This is known as the auto-commit mode. If auto-commit mode is on and you perform a `COMMIT` or `ROLLBACK` operation using the `commit` or `rollback` method on a connection object, then you get the following error messages:

Table 2-2 Error Messages for Operations Performed When Auto-Commit Mode is ON

Operation	Error Messages
`COMMIT`	`Could not commit with auto-commit set on`
`ROLLBACK`	`Could not rollback with auto-commit set on`

If a SQLException is raised during a `COMMIT` or `ROLLBACK` operation with the error messages as mentioned in the preceding table, then check the auto-commit status of the connection because you get an exception when these operations are performed on a connection that has auto-commit value set to `true`.

This exception is raised for any one of the following cases:

- When auto-commit status is set to `true` and `commit` or `rollback` method is called
- When the default status of auto-commit is not changed and `commit` or `rollback` method is called
- When the value of the `COMMIT_ON_ACCEPT_CHANGES` property is `true` and `commit` or `rollback` method is called after calling the `acceptChanges` method on a rowset

However, you can disable auto-commit mode with the following method call on the `Connection` object:

```
conn.setAutoCommit(false);
```

If you disable the auto-commit mode, then you must manually commit or roll back changes with the appropriate method call on the `Connection` object:

```
conn.commit();
```

or:

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```
conn.rollback();
```

A `COMMIT` or `ROLLBACK` operation affects all DML statements run since the last `COMMIT` or `ROLLBACK`.

> **Note**
>
> - If the auto-commit mode is disabled and you close the connection without explicitly committing or rolling back your last changes, then an implicit `COMMIT` operation is run.
> - Any data definition language (DDL) operation always causes an implicit `COMMIT`. If the auto-commit mode is disabled, then this implicit `COMMIT` will commit any pending DML operations that had not yet been explicitly committed or rolled back.

Related Topics

- Disabling Auto-Commit Mode

2.3.8.1 Changing Commit Behavior

When a transaction updates the database, it generates a redo entry corresponding to this update. Oracle Database buffers this redo in memory until the completion of the transaction. When you commit the transaction, the Log Writer (LGWR) process writes the redo entry for the commit to disk, along with the accumulated redo entries of all changes in the transaction. By default, Oracle Database writes the redo to disk before the call returns to the client. This behavior introduces latency in the commit because the application must wait for the redo entry to be persisted on disk.

If your application requires very high transaction throughput and you are willing to trade commit durability for lower commit latency, then you can change the behavior of the default `COMMIT` operation, depending on the needs of your application. You can change the behavior of the `COMMIT` operation with the following options:

- `WAIT`
- `NOWAIT`
- `WRITEBATCH`
- `WRITEIMMED`

These options let you control two different aspects of the commit phase:

- Whether the `COMMIT` call should wait for the server to process it or not. This is achieved by using the `WAIT` or `NOWAIT` option.
- Whether the Log Writer should batch the call or not. This is achieved by using the `WRITEIMMED` or `WRITEBATCH` option.

You can also combine different options together. For example, if you want the `COMMIT` call to return without waiting for the server to process it and also the log writer to process the commits in batch, then you can use the `NOWAIT` and `WRITEBATCH` options together. For example:

```
((OracleConnection)conn).commit(
    EnumSet.of(
      OracleConnection.CommitOption.WRITEBATCH,
      OracleConnection.CommitOption.NOWAIT));
```


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> **Note**
>
> you cannot use the `WAIT` and `NOWAIT` options together because they have opposite meanings. If you do so, then the JDBC driver will throw an exception. The same applies to the `WRITEIMMED` and `WRITEBATCH` options.

2.3.9 Closing the Connection

You must close the connection to the database after you have performed all the required operations and no longer require the connection. You can close the connection by using the `close` method of the `Connection` object, as follows:

```
conn.close();
```

> **Note**
>
> Typically, you should put `close` statements in a `finally` clause.

2.4 Sample: Connecting, Querying, and Processing the Results

The steps in the preceding sections are illustrated in the following example, which uses the Oracle JDBC Thin driver to create a data source, connects to the database, creates a `Statement` object, runs a query, and processes the result set.

Note that the code for creating the `Statement` object, running the query, returning and processing the `ResultSet` object, and closing the statement and connection uses the standard JDBC API.

```
import java.sql.Connection;
import java.sql.ResultSet;
import java.sql.Statement;
import java.sql.SQLException;
import oracle.jdbc.pool.OracleDataSource;

class JdbcTest
{
   public static void main (String args []) throws SQLException
   {

OracleDataSource ods = null;
Connection conn = null;
Statement stmt = null;
ResultSet rset = null;

      // Create DataSource and connect to the local database
      ods = new OracleDataSource();
      ods.setURL("jdbc:oracle:thin:@localhost:5221/orcl");
      ods.setUser("HR");
      ods.setPassword("hr");
      conn = ods.getConnection();

try
{
      // Query the employee names
```


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```
      stmt = conn.createStatement ();
      rset = stmt.executeQuery ("SELECT first_name FROM employees");

      // Print the name out
      while (rset.next ())
         System.out.println (rset.getString (1));
    }

      //Close the result set, statement, and the connection

finally{
      if(rset!=null) rset.close();
      if(stmt!=null) stmt.close();
      if(conn!=null) conn.close();
}
   }
}
```

If you want to adapt the code for the OCI driver, then replace the call to the `OracleDataSource.setURL` method with the following:

```
ods.setURL("jdbc:oracle:oci:@MyHostString");
```

where, `MyHostString` is an entry in the `TNSNAMES.ORA` file.

2.5 Support for JSON-Relational Duality Views

Duality views combine the advantages of using JSON documents with those of the relational model, while avoiding the limitations of each. JSON-relational duality underpins collections of documents with relational storage: active, updatable, hierarchical documents are based on a foundation of normalized relations.

> **See Also**
>
> *Oracle Database JSON-Relational Duality Developer's Guide*

You can retrieve information about JSON-relational duality views using the following JDBC methods:

- `isDualityView()`
- `getJsonSchema()`

> **See Also**
>
> Oracle Database JDBC Java API Reference

The following code snippet shows how to use these methods:

```
OracleDatabaseMetaData metaData = new
OracleDatabaseMetaData((OracleConnection) conn);

      System.out.println("Is Duality View: " +
metaData.isDualityView("DEPARTMENT_DV"));
```


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```
ResultSet rs = metaData.getJsonSchema("DEPARTMENT_DV");
if (rs.next()) {
  System.out.println("JSON Schema: " + rs.getString(1));
}
```

> **See Also**
>
> oracle-db-examples folder on GitHub for more examples

2.6 Support for Fixed Character Semantic

Starting from Oracle AI Database Release 26ai, you can change the default parameter mapping of a Java String to its Oracle Type, using the new connection property `oracle.jdbc.mapStringParameterToCHAR`.

The default value of this property is `false`. If you set this property to `true`, then the JDBC driver uses fixed character semantic when the `setString` method is called. Calls to the `setObject` method, with a parameter of type `String`, also uses a fixed character semantic. This is essential because when you run a query using collation or Extended Binary Coded Decimal Interchange Code (EBCDIC), you must typecast a Java `String` to `CHAR` instead `VARCHAR2` because `VARCHAR2` is incompatible with DB2 `VARCHAR`.

> **See Also**
>
> Oracle AI Database JDBC Java API Reference for more information about this property

2.7 Support for Java Virtual Threads

Starting from Oracle Database Release 21c, JDBC drivers support virtual threads. A virtual thread is an instance of `java.lang.Thread`, which is not tied to a specific operating system (OS) thread.

A virtual thread too runs the code on an OS thread; however, when the code running in a virtual thread calls a blocking I/O operation, then the Java run time suspends the virtual thread until it can be resumed. So, you can use virtual threads for long-running tasks that are blocked most of the time, often waiting for I/O operations to complete.

> **See Also**
>
> Java SE Core Libraries

2.8 Support for Annotations

Annotations are a lightweight declarative facility for developers to centrally register usage properties for database schema objects.

You can add annotations to schema objects when you create new objects (using the `CREATE` statement) or modify existing objects (using the `ALTER` statement). An individual annotation has

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a name and an optional value, both of which are free-form text fields. A schema object can have multiple annotations.

> **See Also**
>
> Application Usage Annotations

Starting from Oracle AI Database Release 26ai, the JDBC drivers support annotations. You can use the following methods to work with annotations:

```
oracle.jdbc.AdditionalDatabaseMetaData.getAnnotations
(java.lang.String objectName, java.lang.String domainName,
java.lang.String domainOwner) throws java.sql.SQLException


oracle.jdbc.OracleResultSetMetaData.getAnnotations
(java.lang.String objectName, java.lang.String columnName,
java.lang.String domainName, java.lang.String domainOwner) throws
java.sql.SQLException
```

These methods return the annotations associated with the specified table or view. If there is no annotation available for the specified object, then it returns null.

2.9 Support for Oracle True Cache

Oracle True Cache is an in-memory, consistent, and automatically managed cache for Oracle Database. It satisfies queries by using data only from its buffer cache.

True Cache is a fully functional, read-only replication of the primary database, which is mostly diskless. It exploits the fact that the applications rarely need the most current data, and can use the cached data instead. Queries that use the cached data, can be issued to a True Cache instance that is in the middle tier. So, the applications need to maintain two data sources, one to the primary database and the other to the True Cache instance.

> **See Also**
>
> Oracle Database Oracle True Cache User's Guide

When configured, the JDBC driver can execute queries on both the True Cache instance and the primary database. Applications maintain only one logical connection, which is aware of both the primary database and the True Cache instance. A query is executed on the True Cache instance if the JDBC driver logical connection is in a read-only mode, otherwise, the query is executed on the primary database. This improves the scalability and the application-response-time because the number of queries sent to the primary database is reduced.

For enabling the True Cache functionality, you must set the value of the new `oracle.jdbc.useTrueCacheDriverConnection` property to `true`. Once you enable the True Cache functionality, the JDBC driver uses the standard `java.sql.Connection.setReadOnly(boolean)` and `java.sql.Connection.isReadOnly()` methods to mark a connection as read-only. By default, the read-only mode is `false` for a connection.

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The following code snippet shows how to use the True Cache functionality:

```
...
OracleDataSource ods = new oracle.jdbc.pool.OracleDataSource();
ods.setURL(DB_URL);
ods.setUser(DB_USER);
ods.setPassword(DB_PASSWORD);
Properties props = new Properties();
props.setProperty("oracle.jdbc.useTrueCacheDriverConnection", "true");
ods.setConnectionProperties(props);
// this is a True Cache driver connection and it can be used to execute
// queries on both the primary database and a True Cache instance
Connection conn = ods.getConnection();
Statement stmt = conn.createStatement();
// Default value of connection read-only flag is false which means
// the SQL_QUERY1 is executed on the primary database
ResultSet rs = stmt.executeQuery(SQL_QUERY1);
// set the read-only flag to true, in order to execute SQL_QUERY2
// on a True Cache instance
conn.setReadOnly(true);
ResultSet rs1 = stmt.executeQuery(SQL_QUERY2);
...
```

See Also

- setReadOnly(boolean) method
- isReadOnly method

2.10 Support for the Bequeath Protocol

Starting from Oracle AI Database Release 26ai, the JDBC thin driver supports the Bequeath protocol (BEQ) for applications running on Linux platforms.

To connect to the Database using the Bequeath Protocol, you must set the value of the `ORACLE_HOME` variable, so that the driver can locate the Oracle server process executable. Typically, the `ORACLE_HOME` variable points to the database installation location, that is, `/var/lib/oracle/dbhome`. You can reset the location in the following two ways:

- In the connection URL
- In the environment of the current application

The second mandatory variable, which you must enable, is the `ORACLE_SID`. Similar to setting the `ORACLE_HOME` variable, you can set the `ORACLE_SID` in the connection URL or in the current application environment. To establish a bequeath connection, the BEQ protocol must be enabled, which is the default setting in the authentication services property.

The following example shows how you can set the `ORACLE_HOME` variable and the `ORACLE_SID` in the connection URL:

```
jdbc:oracle:thin:@(DESCRIPTION=(LOCAL=YES)(ADDRESS=(PROTOCOL=beq))
(ENVS=ORACLE_HOME=/var/lib/oracle/dbhome,ORACLE_SID=oraclesid))
```


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> **See Also**
>
> Oracle JDBC Java API Reference

2.11 Support for Invisible Columns

Starting from this release, Oracle Database supports invisible columns. Using this feature, you can add a column to the table in hidden mode and make it visible later. JDBC provides APIs to retrieve information about invisible columns. To get information about whether a column is invisible or not, you can use the `isColumnInvisible` method available in the `oracle.jdbc.OracleResultSetMetaData` interface in the following way:

Example

```
...
Connection conn = DriverManager.getConnection(jdbcURL, user, password);
Statement stmt = conn.createStatement ();
stmt.executeQuery ("create table hiddenColsTable (a varchar(20), b int invisible)");
stmt.executeUpdate("insert into hiddenColsTable (a,b ) values('somedata',1)");
stmt.executeUpdate("insert into hiddenColsTable (a,b) values('newdata',2)");

System.out.println ("Invisible columns information");
try
{
      ResultSet rset = stmt.executeQuery("SELECT a, b FROM hiddenColsTable");
      OracleResultSetMetaData rsmd = (OracleResultSetMetaData)rset.getMetaData();
      while (rset.next())
      {
        System.out.println("column1 value:" + rset.getString(1));
        System.out.println("Visibility:" + rsmd.isColumnInvisible(1));
        System.out.println("column2 value:" + rset.getInt(2));
        System.out.println("Visibility:" + rsmd.isColumnInvisible(2));
      }
}
catch (Exception ex)
{
       System.out.println("Exception :" + ex);
       ex.printStackTrace();
}
```

Alternatively, you can also use the `getColumns` method available in the `oracle.jdbc.OracleDatabaseMetaData` class to retrieve information about invisible columns.

Example

```
...
Connection conn = DriverManager.getConnection(jdbcURL, user, password);
Statement stmt = conn.createStatement ();
stmt.executeQuery ("create table hiddenColsTable (a varchar(20), b int invisible)");
stmt.executeUpdate("insert into hiddenColsTable (a,b ) values('somedata',1)");
stmt.executeUpdate("insert into hiddenColsTable (a,b) values('newdata',2)");

 System.out.println ("getColumns for table with invisible columns");
 try
 {
      DatabaseMetaData dbmd = conn.getMetaData();
      ResultSet rs = dbmd.getColumns(null, "HR", "hiddenColsTable", null);
      OracleResultSetMetaData rsmd = (OracleResultSetMetaData)rs.getMetaData();
```


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```
     int colCount = rsmd.getColumnCount();
     System.out.println("colCount: " + colCount);
     String[] columnNames = new String [colCount];

     for (int i = 0; i < colCount; ++i)
     {
       columnNames[i] = rsmd.getColumnName (i + 1);
     }

     while (rs.next())
     {
       for (int i = 0; i < colCount; ++i)
          System.out.println(columnNames[i] +":" +rs.getString (columnNames[i]));
     }
}
catch (Exception ex)
{
     System.out.println("Exception: " + ex);
     ex.printStackTrace();
}
```

> **Note**
>
> The server-side internal driver, `kprb` does not support fetching information about invisible columns.

2.12 Support for Verifying JSON Data

Starting from Oracle Database Release 18c, JDBC drivers can verify whether a column returned in the `ResultSet` is a JSON column or not. To get information about whether a column is JSON or not, you can use the `isColumnJSON` method available in the `oracle.jdbc.OracleResultSetMetaData` interface in the following way:

Example 2-1 Example

```
  ...
  public void test(Connection conn)
      throws Exception{

    try {
      show ("tkpjb26776242 - start");
      createTable(conn);

      String sql = "SELECT col1, col2, col3, col4, col5, col6, col7, col8
FROM tkpjb26776242_tab";
      Statement stmt = conn.createStatement();
      ResultSet rs = stmt.executeQuery(sql);
      ResultSetMetaData rsmd = rs.getMetaData();

      OracleResultSetMetaData orsmd   = (OracleResultSetMetaData)rsmd;

      int colCnt = orsmd.getColumnCount();
      show("Table has " + colCnt + " columns.");
```


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```
      for (int i = 1; i <= colCnt; i++) {
        String columnName = orsmd.getColumnName(i);
        String typeName = orsmd.getColumnTypeName(i);
        boolean invisible = orsmd.isColumnInvisible(i);
        boolean json = orsmd.isColumnJSON(i);
        show(columnName + "  " + typeName + (invisible?"   INVISIBLE":"") +
(json?"   JSON":""));
      }

      rs.close();
      stmt.close();

      show ("tkpjb26776242 - end");
    }
    finally {
      dropTable(conn);
    }
  }


  private void createTable(Connection conn) throws Exception{
    String sql = " create table tkpjb26776242_tab ( "
                 + "  col1 clob, "
                 + " col2 clob , "
                 + " col3 clob INVISIBLE, "
                 + " col4 clob INVISIBLE, "
                 + " col5 varchar2(200), "
                 + " col6 varchar2(200), "
                 + " col7 varchar2(200) INVISIBLE, "
                 + " col8 varchar2(200) INVISIBLE, "
                 + " check (col2 IS JSON), "
                 + " check (col4 IS JSON), "
                 + " check (col6 IS JSON), "
                 + " check (col8 IS JSON))";

    Util.doSQL(conn, sql);
  }

  private void dropTable(Connection conn) throws Exception{
    String sql = " drop table tkpjb26776242_tab";

    Util.trySQL(conn, sql);
  }
    ...
```

2.13 Support for Implicit Results

Oracle Database supports results of SQL statements executed in a stored procedure to be returned implicitly to the client applications without the need to explicitly use a `REF CURSOR`.

You can use the following methods to retrieve and process the implicit results returned by PL/SQL procedures or blocks:

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Method	Description
`getMoreResults`	Checks if there are more results available in the result set
`getMoreResults(int)`	Checks if there are more results available in the result set, like the overloaded method. This method accepts an `int` parameter that can have one of the following values: • `KEEP_CURRENT_RESULT` • `CLOSE_ALL_RESULTS` • `CLOSE_CURRENT_RESULT`
`getResultSet`	Iteratively retrieves each implicit result from an executed PL/SQL statement

Note

- The server-side internal driver, `kprb` does not support fetching information about implicit results.
- Only SELECT queries can be returned implicitly.
- Applications retrieve each result set sequentially, but can fetch rows from any result set independent of the sequence.

Suppose you have a procedure called `foo` as the following:

```
 create procedure foo as
  c1 sys_refcursor;
  c2 sys_refcursor;
begin
  open c1 for select * from hr.employees;
  dbms_sql.return_result(c1); --return to client
  -- open 1 more cursor
  open c2 for select * from hr.departments;
  dbms_sql.return_result (c2); --return to client
end;
```

The following code snippet demonstrates how to retrieve the implicit results returned by PL/SQL procedures using the `getMoreResults` methods:

Example 1

```
String sql = "begin foo; end;";
...
Connection conn = DriverManager.getConnection(jdbcURL, user, password);
 try {
        Statement stmt = conn.createStatement ();
        stmt.executeQuery (sql);

        while (stmt.getMoreResults())
        {
              ResultSet rs = stmt.getResultSet();
              System.out.println("ResultSet");
              while (rs.next())
             {
                   /* get results */
             }
```


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```
        }
    }
```

Suppose you have another procedure called `foo` as the following:

```
create or replace procedure foo asc1 sys_refcursor; c2 sys_refcursor; c3 sys_refcursor;
begin   open c1 for 'select * from hr.employees';
dbms_sql.return_result (c1);-- cursor 2open c2 for 'select * from hr.departments';
dbms_sql.return_result (c2);-- cursor 3open c3 for 'select first_name from hr.employees';
dbms_sql.return_result (c3); end;
```

The following code snippet demonstrates how to retrieve the implicit results returned by PL/SQL procedures using the `getMoreResults(int)` methods:

Example 2

```
String sql = "begin foo; end;";
...
Connection conn = DriverManager.getConnection(jdbcURL, user, password);

try {
        Statement stmt = conn.createStatement ();
        stmt.executeQuery (sql);
        ResultSet rs = null;

        boolean retval = stmt.getMoreResults(Statement.KEEP_CURRENT_RESULT))
        if (retval)
        {
            rs = stmt.getResultSet();
            System.out.println("ResultSet");
            while (rs.next())
            {
                /* get results */
            }
        }

        /* closes open results */
        retval = stmt.getMoreResults(Statement.CLOSE_ALL_RESULTS);

        if (retval)
        {
            System.out.println("More ResultSet available");
            rs = stmt.getResultSet();
            System.out.println("ResultSet");
            while (rs.next())
            {
                /* get results */
            }
        }

        /* close current result set */
        retval = stmt.getMoreResults(Statement.CLOSE_CURRENT_RESULT);

        if(retval)
        {
            System.out.println("More ResultSet available");
            rs = stmt.getResultSet();
            while (rs.next())
            {
                /* get Results */

            }
```


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```
        }
    }
```

2.14 Support for Lightweight Connection Validation

Starting from Oracle Database Release 18c, JDBC Thin driver supports lightweight connection validation. Lightweight connection validation enables JDBC applications to verify connection validity by sending a zero length NS data packet that does not require a round-trip to the database.

For the releases of Oracle Database earlier than 18c, when you call the `isValid(timeout)` method to test the validity of a connection, Oracle JDBC driver uses a ping-pong protocol, which is an expensive operation as it makes a full round-trip to the database. Since Oracle Database Release 18c, the `isValid(timeout)` method instead sends an empty packet to the database and does not wait to receive it back. So, connection validation is faster, which results in better application performance.

Lightweight connection validation is disabled by default. To enable this feature, you must set the `oracle.jdbc.defaultConnectionValidation` connection property value to `SOCKET`. If this property is set, then the JDBC driver performs lightweight connection validation, when you call the `isValid(timeout)` method.

> **Note**
>
> - Lightweight connection validation checks only the underlying socket health. When the `isValid(timeout)` method returns `true`, that is, if a connection is termed as valid, this validation only guarantees that the server is not unreachable (dead socket). It does not provide any status about the server processes, like whether they are running or not. However, by default, that is, when lightweight connection validation is not enabled, the `isValid(timeout)` method does check whether the network between the client and the server is intact or not.
> - Only the JDBC Thin driver supports this feature.

New APIs for Lightweight Connection Validation

- `oracle.jdbc.defaultConnectionValidation`

  This connection property specifies the level of connection validation. The possible values for this property are: `NONE`, `LOCAL`, `SOCKET`, `NETWORK`, `SERVER`, and `COMPLETE`. These values are case-sensitive, and setting any value other than these values throws an exception. The default value is `NETWORK`.

- `public boolean isValid(ConnectionValidation validation_level, int timeout) throws SQLException`

  The new variation of the existing `isValid(timeout)` method accepts two parameters: level of validation (`validation_level`) and `timeout`. The first parameter specifies the level of connection validation.

Example 2-2 Example of Lightweight Connection Validation

The following code snippet demonstrates how to implement lightweight connection mechanism:

```
...
OracleDataSource ods = new OracleDataSource();
```


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```
    ods.setURL(url);
    ods.setUser(user);
    ods.setPassword(password);
    Connection conn = ods.getConnection();
    try{
          boolean isValid = ((OracleConnection)conn).

isValid(ConnectionValidation.SOCKET,timeout);
          System.out.println("Connection isValid = "+isValid);
    }
    catch (Exception ex)
   {
         System.out.println("Exception :" + ex);
         ex.printStackTrace();
    }
    ...    ...
```

2.15 Support for Deprioritization of Database Nodes

Starting from Oracle Database 12*c* Release 2 (12.2.0.1), JDBC drivers support deprioritization of database nodes. When a node fails, JDBC deprioritizes it for the next 10 minutes, which is the default expiry time. For example, if there are three nodes A, B, C, and node A is down, then connections are allocated first from nodes B and C, and then from node A. After the default expiry time, node A is no longer deprioritized, that is, connections are allocated from all the three nodes on availability basis. Also, during the default expiry time, if a connection attempt to node A succeeds, then node A is no longer considered to be a deprioritized node. You can specify the default expiry time for deprioritization using the `oracle.net.DOWN_HOSTS_TIMEOUT` system property.

For example, in the following URL, `scan_listener0` has `ip1`, `ip2`, and `ip3` IP addresses configured, after retrieving its IP addresses. Now, if `ip1` is deprioritized, then the order of trying IP addresses will be `ip2`, `ip3`, and then `ip1`. If all IP addresses are unavailable, then the whole host is tried last, after trying `node_1` and `node_2`.

```
(DESCRIPTION_LIST=
    (DESCRIPTION=
        (ADDRESS_LIST=
            (ADDRESS=(PROTOCOL=tcp)(HOST=scan_listener0)(PORT=1521))
            (ADDRESS=(PROTOCOL=tcp)(HOST=node_1)(PORT=1528))
            (ADDRESS=(PROTOCOL=sdp)(HOST=node_2)(PORT=1527))
        )
        (ADDRESS_LIST=
            (ADDRESS=(PROTOCOL=tcp)(HOST=node_3)(PORT=1528))
        )
        (CONNECT_DATA=(SERVICE_NAME=cdb3))
    )
    (DESCRIPTION=
        (ADDRESS=(PROTOCOL=tcp)(HOST=node_0)(PORT=1528))
        (CONNECT_DATA=(SERVICE_NAME=cdb3))
    )
)
```


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2.16 Support for Oracle Connection Manager in Traffic Director Mode

Starting from Oracle Database Release 18c, JDBC Drivers support Oracle Connection Manager in Traffic Director Mode, which is a proxy server that resides between the Database clients and the Database instances.

A JDBC client connects to the Oracle Connection Manager in Traffic Director Mode, which in turn connects to the target Oracle Database. The client sends requests in the form of Two-Task Common (TTC) messages that Oracle Connection Manager in Traffic Director Mode intercepts, parses, and then relays to the appropriate target database. Once the responses arrive from the database, Oracle Connection Manager in Traffic Director Mode transfers the responses back to the clients through TTC messages.

The following image illustrates the architecture of Oracle Connection Manager in Traffic Director Mode:

Figure 2-1 Architecture of Oracle Connection Manager in Traffic Director Mode

See Also

- *Oracle AI Database Net Services Administrator's Guide* for more information about configuring the `cman.ora` file to set up Oracle Connection Manager in Traffic Director Mode
- *Oracle AI Database Net Services Reference* for more information about Oracle Connection Manager in Traffic Director Mode parameters

This chapter describes the following concepts:

- Modes of Running Oracle Connection Manager in Traffic Director Mode

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- Benefits of Oracle Connection Manager in Traffic Director Mode

2.16.1 Modes of Running Oracle Connection Manager in Traffic Director Mode

You can run Oracle Connection Manager in Traffic Director Mode in the following connection modes:

- **Pooled connection mode**

  The pooled connection mode uses a new feature called Proxy Resident Connection Pooling, which is a proxy-enabled mode of Database Resident Connection Pooling (DRCP). The Proxy Resident Connection Pooling reduces the connection load on the database as it multiplexes a large number of client connections over a fewer number of database connections. Any application using Oracle Database 12*c* Release 1 (12.1) JDBC drivers and later can use this connection mode.

  > **Note**
  >
  > The pooled connection mode yields best results when you use it with clients using DRCP-aware connection pools.

- **Nonpooled or dedicated connection mode**

  You can use the nonpooled or dedicated connection mode with applications using any supported Oracle Database JDBC driver. However, some capabilities, such as connection multiplexing, are not available in this mode.

Related Topics

- Overview of Database Resident Connection Pooling

> **See Also**
>
> - Database Admin Guide
> - Universal Connection Pool Developer's Guide

2.16.2 Benefits of Oracle Connection Manager in Traffic Director Mode

This section describes how Oracle Connection Manager in Traffic Director Mode provides benefits to your applications.

- **Transparent performance enhancements:** Oracle Connection Manager in Traffic Director Mode auto enables statement caching, row prefetching, and result set caching during both pooled and nonpooled modes.
- **Connection multiplexing:** Using Proxy Resident Connection Pooling (PRCP), Oracle Connection Manager in Traffic Director Mode (for the pooled mode) provides transparent connection-time load balancing and run-time load balancing with the database. If you use multiple instances of Oracle Connection Manager in Traffic Director Mode, then you can increase the scalability of your application through the implementation of client-side connection-time load balancing or a load balancer like BIG-IP or NGINX.

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- **Zero application downtime:** Oracle Connection Manager in Traffic Director Mode provides zero application downtime during planned database maintenance as well as unplanned database outages. For Unplanned database outages, it offers zero application downtime for read-mostly workloads. For planned database maintenance or pluggable database (PDB) relocation, it uses different techniques for the pooled mode and the nonpooled mode, as described in this section.
  - Pooled mode:

    For planned outages, Oracle Connection Manager in Traffic Director Mode responds to the Oracle Notification Service (ONS) events. It uses database connections from the proxy resident connection pool and redirects the requests to the appropriate databases. When the requests complete, it drains the connections from the pool.

    For PDB relocations, Oracle Connection Manager in Traffic Director Mode uses an in-band client notification mechanism, which works even when ONS is not configured. This feature is available only for Oracle Database release 18c and later.
  - Nonpooled or dedicated mode

    In this mode, Oracle Connection Manager in Traffic Director Mode leverages either of the following features of Oracle Database:

    * Continuous application availability to stop the service at the request boundary
    * Transparent Application Failover (TAF) to reconnect and restore simple states
- **High Availability:** Oracle Connection Manager in Traffic Director Mode implements the following techniques to avoid single point of failure, and in turn, assures high availability:
  - Multiple instances of Oracle Connection Manager in Traffic Director Mode use a load balancer or client-side load balancing in the connection string.
  - Oracle Connection Manager in Traffic Director Mode instances support rolling upgrade.
  - For planned outages, Oracle Connection Manager in Traffic Director Mode implements graceful close of existing connections from client.
  - Oracle Connection Manager in Traffic Director Mode sends in-band notifications to Oracle Database release 18c and later clients, and ONS notifications to all supported clients prior to Oracle Database release 18c.
- **Security:** Oracle Connection Manager in Traffic Director Mode provides security to your applications in the following ways:
  - It supports the Transmission Control Protocol Secure (TCPS) protocol.
  - It creates a firewall based on the IP address, service name, and Transport Layer Security (TLS) wallets.
  - It provides protection against denial-of-service and fuzzing attacks.
  - It provides secure tunneling of database traffic across Oracle Database on-premises and Oracle Cloud.
- **Tenant isolation:** Oracle Connection Manager in Traffic Director Mode provides tenant isolation for increased memory and enhanced processing power.

2.17 Stored Procedure Calls in JDBC Programs

This section describes how Oracle JDBC drivers support the following kinds of stored procedures:

- PL/SQL Stored Procedures

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- Java Stored Procedures

2.17.1 PL/SQL Stored Procedures

JDBC supports the invocation of PL/SQL procedures/functions and anonymous blocks, using either JDBC escape syntax or PL/SQL block syntax. The following PL/SQL calls would work with any Oracle JDBC driver:

```
// JDBC escape syntax
CallableStatement cs1 = conn.prepareCall
                        ( "{call proc (?,?)}" ) ; // stored proc
CallableStatement cs2 = conn.prepareCall
                        ( "{? = call func (?,?)}" ) ; // stored func
// PL/SQL block syntax
CallableStatement cs3 = conn.prepareCall
                        ( "begin proc (?,?); end;" ) ; // stored proc
CallableStatement cs4 = conn.prepareCall
                        ( "begin ? := func(?,?); end;" ) ; // stored func
```

As an example of using the Oracle syntax, here is a PL/SQL code snippet that creates a stored function. The PL/SQL function gets a character sequence and concatenates a suffix to it:

```
create or replace function foo (val1 char)
return char as
begin
   return val1 || 'suffix';
end;
```

The function invocation in your JDBC program should look like the following:

```
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:oracle:oci:@<hoststring>");
ods.setUser("HR");
ods.setPassword("hr");
Connection conn = ods.getConnection();

CallableStatement cs = conn.prepareCall ("begin ? := foo(?); end;");
cs.registerOutParameter(1,Types.CHAR);
cs.setString(2, "aa");
cs.execute();
String result = cs.getString(1);
```

2.17.2 Java Stored Procedures

You can use JDBC to call Java stored procedures through the SQL interface. The syntax for calling Java stored procedures is the same as the syntax for calling PL/SQL stored procedures, presuming they have been properly published. That is, you have written call specifications to publish them to the Oracle data dictionary. Applications can call Java stored procedures using the Native Java Interface for direct invocation of `static` Java methods.

2.18 About Processing SQL Exceptions

To handle error conditions, Oracle JDBC drivers throw SQL exceptions, producing instances of the `java.sql.SQLException` class or its subclass. Errors can originate either in the JDBC driver or in the database itself. Resulting messages describe the error and identify the method that threw the error. Additional run-time information can also be appended.

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JDBC 3.0 defines only a single exception, `SQLException`. However, there are large categories of errors and it is useful to distinguish them. Therefore, in JDBC 4.0, a set of subclasses of the `SQLException` exception is introduced to identify the different categories of errors.

Basic exception handling can include retrieving the error message, retrieving the error code, retrieving the SQL state, and printing the stack trace. The `SQLException` class includes functionality to retrieve all of this information, when available.

Retrieving Error Information

You can retrieve basic error information with the following methods of the `SQLException` class:

- `getMessage` class includes functionality to retrieve all of this information, when available.
- `getErrorCode` class includes functionality to retrieve all of this information, when available.
- `getSQLState` class includes functionality to retrieve all of this information, when available.

The following example prints output from a `getMessage` method call:

```
catch(SQLException e)
{
   System.out.println("exception: " + e.getMessage());
}
```

This would print the output, such as the following, for an error originating in the JDBC driver:

```
exception: Invalid column type
```

> **Note**
>
> Error message text is available in alternative languages and character sets supported by Oracle.

Printing the Stack Trace

The `SQLException` class provides the `printStackTrace()` method for printing a stack trace. This method prints the stack trace of the `Throwable` object to the standard error stream. You can also specify a `java.io.PrintStream` object or `java.io.PrintWriter` object for output.

The following code fragment illustrates how you can catch SQL exceptions and print the stack trace.

```
try { <some code> }
catch(SQLException e) { e.printStackTrace (); }
```

To illustrate how the JDBC drivers handle errors, assume the following code uses an incorrect column index:

```
// Iterate through the result and print the employee names
// of the code

try {
  while (rset.next ())
      System.out.println (rset.getString (5));  // incorrect column index
}
catch(SQLException e) { e.printStackTrace (); }
```


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Assuming the column index is incorrect, running the program would produce the following error text:

```
java.sql.SQLException: Invalid column index
at oracle.jdbc.OracleDriver.OracleResultSetImpl.getDate(OracleResultSetImpl.java:1556)
at Employee.main(Employee.java:41)
```

Related Topics

- JDBC Error Messages
  All the JDBC error messages are now listed in the Database Error Portal.

> **See Also**
>
> Database Error Messages Help Portal

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Part II
Oracle JDBC

This part includes chapters that discuss the different Java Database Connectivity (JDBC) versions that Oracle AI Database Release 26ai supports. It also includes chapters that cover features specific to JDBC Thin driver, JDBC Oracle Call Interface (OCI) driver, and the server-side internal driver.

Part II contains the following chapters:

- JDBC Standards Support
- Oracle Extensions
- Features Specific to JDBC Thin
- Features Specific to JDBC OCI Driver
- Server-Side Internal Driver

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3

JDBC Standards Support

Oracle Java Database Connectivity (JDBC) drivers support different versions of the JDBC standard features. These features are provided through the `oracle.jdbc` and `oracle.sql` packages. These packages support JDK 8, JDK 11, and JDK 17.

This chapter discusses the JDBC standards support in Oracle JDBC drivers for the most recent releases. It contains the following sections:

- Support for JDBC 4.2 Standard
- Support for JDBC 4.3 Standard

3.1 Support for JDBC 4.2 Standard

Oracle Database Release 23ai JDBC drivers provide support for JDBC 4.2 standard through JDK 8. This section lists some of the important methods available in this release.

The %Large% Methods

This release of Oracle JDBC drivers support the following methods introduced in JDBC 4.2 standard, which deal with `long` values:

- `executeLargeBatch()`
- `executeLargeUpdate(String sql)`
- `executeLargeUpdate(String sql, int autoGeneratedKeys)`
- `executeLargeUpdate(String sql, int[] columnIndexes)`
- `executeLargeUpdate(String sql, String[] columnNames)`
- `getLargeMaxRows()`
- `getLargeUpdateCount()`
- `setLargeMaxRows(long max)`

These new methods are available as part of the `java.sql.Statement` interface. The `%Large%` methods are identical to the corresponding *non-large* methods, except that they work with `long` values instead of `int` values. For example, the `executeUpdate` method returns the number of rows updated as an `int` value, whereas, the `executeLargeUpdate` method returns the number of rows updated as a `long` value. If the number of rows is greater than the value of `Integer.MAX_VALUE`, then your application must use the `executeLargeUpdate` method.

The following code snippet shows how to use the `executeLargeUpdate(String sql)` method:

```
...
Statement stmt = conn.createStatement();
stmt.executeQuery("create table BloggersData (FIRST_NAME varchar(100), ID
int)");
long updateCount = stmt.executeLargeUpdate("insert into BloggersData
(FIRST_NAME,ID) values('John',1)");
...
```


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The SQLType Methods

This release of Oracle JDBC drivers support the following methods introduced in JDBC 4.2 standard, which take `SQLType` parameters:

- `setObject`

  The `setObject` method sets the value of the designated parameter for the specified object. This method is similar to the `setObject(int parameterIndex, Object x, SQLType targetSqlType, int scaleOrLength)` method, except that it assumes a scale of zero. The default implementation of this method throws `SQLFeatureNotSupportedException`.

  ```
  void setObject(int parameterIndex, java.lang.Object x, SQLType
  targetSqlType) throws SQLException
  ```

- `updateObject`

  The `updateObject` method takes the column index as a parameter and updates the designated column with an Object value.

- `registerOutParameter`

  The `registerOutParameter` method registers a specified parameter to be of JDBC type `SQLType`.

The following code snippet shows how to use the `setObject` method:

```
...
int empId = 100;
connection.prepareStatement("SELECT FIRST_NAME, LAST_NAME FROM EMPLOYEES
WHERE EMPNO = ?");
preparedStatement.setObject(1, Integer.valueOf(empId), OracleType.NUMBER);
...
```

See Also

JDBC 4.2 Documentation

3.2 Support for JDBC 4.3 Standard

Starting from Release 19c, Oracle Database JDBC drivers provide support for Standard JDBC 4.3 features through JDK 11 and JDK 17. This section describes some of the important APIs available in this release.

Sharding Support

Sharding is a data tier architecture, where data is horizontally partitioned across independent databases. Each database in such a configuration is called a shard. All shards together make up a single logical database, which is referred to as a sharded database (SDB). You can use the `DatabaseMetaData.supportsSharding` method to determine whether a JDBC Driver supports sharding or not.

Sharding support includes addition of the following APIs:

- `javax.sql.XAConnectionBuilder` Interface

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This is a builder interface created from a `XADataSource` object, which you can use to establish a connection to the database that the data source object represents.

- `java.sql.ShardingKey` Interface
  This interface is used to indicate that the current object represents a Sharding Key. You can create a `ShardingKey` instance using the `ShardingKeyBuilder` interface.
- `java.sql.ShardingKeyBuilder` Interface
  This is a builder interface created from a `DataSource` or `XADataSource` object, used to create a `ShardingKey` with subkeys of supported data types.

> **See Also**
>
> Overview of Database Sharding for JDBC Users

Enhancements to the java.sql.Connection Interface

The following methods have been added to the `java.sql.Connection` Interface:

- `default void beginRequest throws SQLException`
- `default void endRequest throws SQLException`
- `default void setShardingKey(ShardingKey shardingKey) throws SQLException`
- `default void setShardingKey(ShardingKey shardingKey, ShardingKey superShardingKey) throws SQLException`
- `default void setShardingKeyIfValid(ShardingKey shardingKey, int timeout) throws SQLException`
- `default void setShardingKeyIfValid(ShardingKey shardingKey, ShardingKey superShardingKey, int timeout) throws SQLException`

Enhancements to the java.sql.DatabaseMetaData Interface

The following methods have been added to the `java.sql.DatabaseMetaData` Interface:

```
default boolean supportsSharding() throws SQLException
```

Enhancements to the java.sql.Statement Interface

The following methods have been added to the `java.sql.Statement` Interface:

- `default String enquoteIdentifier(String identifier, Boolean alwaysQuote) throws SQLException`
- `default String enquoteLiteral(String val) throws SQLException`
- `default String enquoteNCharLiteral(String val) throws SQLException`
- `default boolean isSimpleIdentifier(String identifier) throws SQLException`

> **See Also**
>
> Oracle Database JDBC Java API Reference

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4

Oracle Extensions

Oracle provides Java classes and interfaces that extend the Java Database Connectivity (JDBC) standard implementation, enabling you to access and manipulate Oracle data types and use Oracle performance extensions. This chapter provides an overview of the classes and interfaces provided by Oracle that extend the JDBC standard implementation. It also describes some of the key support features of the extensions.

This chapter contains the following sections:

- Overview of Oracle Extensions
- Features of the Oracle Extensions
- Oracle JDBC Packages
- Oracle Character Data Types Support
- Additional Oracle Type Extensions
- DML Returning
- Accessing PL/SQL Associative Arrays

Related Topics

- Performance Extensions

4.1 Overview of Oracle Extensions

Beyond standard features, Oracle JDBC drivers provide Oracle-specific type extensions and performance extensions. These extensions are provided through the following Java packages:

- `oracle.sql`

  Provides classes that represent SQL data in Oracle format

- `oracle.jdbc`

  Provides interfaces to support database access and updates in Oracle type formats

Related Topics

- Oracle JDBC Packages

4.2 Features of the Oracle Extensions

The Oracle extensions to JDBC include a number of features that enhance your ability to work with Oracle Databases. These include the following:

- Support for Pipelined Database Operations
- Database Management Using JDBC
- Support for Oracle Data Types
- Support for Oracle Objects

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- Support for Schema Naming
- DML Returning
- About Accessing PL/SQL Associative Arrays

4.2.1 Database Management Using JDBC

Starting from Oracle Database 11*g* Release 1, the `oracle.jdbc.OracleConnection` interface has two JDBC methods, `startup` and `shutdown`, which enable you to start up and shut down an Oracle Database instance.

> **Note**
>
> My Oracle Support Note 335754.1 announces the desupport of the `oracle.jdbc.driver.*` package in Oracle Database 11*g* JDBC drivers. In other words, Oracle Database 10*g* Release 2 was the last database to support this package and any API depending on the `oracle.jdbc.driver.*` package will fail to compile in the current release of the Database. You must remove such APIs and migrate to the standard APIs. For example, if your code uses the `oracle.jdbc.CustomDatum` and `oracle.jdbc.CustomDatumFactory` interfaces, then you must replace them with the `java.sql.Struct` or `java.sql.SQLData` interfaces.

Related Topics

- Database Administration

4.2.2 Support for Oracle Data Types

One of the features of the Oracle JDBC extensions is the type support in the `oracle.sql` package. This package includes classes that are an exact representation of the data in Oracle format. Keep the following important points in mind, when you use `oracle.sql` types in your program:

- For numeric type of data, the conversion to standard Java types does not guarantee to retain full precision due to limitations of the data conversion process. Use the `BigDecimal` type to minimize any data loss issues.
- For certain data types, the conversion to standard Java types can be dependent on the system settings and your program may not run as expected. This is a known limitation while converting data from `oracle.sql` types to standard Java types.
- If the functionalities of your program is limited to reading data from one table and writing the same to another table, then for numeric and date data, `oracle.sql` types are slightly faster as compared to standard Java types. But, if your program involves even a simple data manipulation operation like compare or print, then standard Java types are faster.
- `oracle.sql.CHAR` is not an exact representation of the data in Oracle format. `oracle.sql.CHAR` is constructed from `java.lang.String`. There is no advantage of using `oracle.sql.CHAR` because `java.lang.String` is always faster and represents the same character sets, excluding a couple of desupported character sets.

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> **Note**
>
> Oracle strongly recommends you to use standard Java types and convert any existing `oracle.sql` type of data to standard Java types. Internally, the Oracle JDBC drivers strive to maximize the performance of Java standard types. `oracle.sql` types are supported *only* for backward compatibility and their use is discouraged.

Related Topics

- Package oracle.sql
  The `oracle.sql` package supports direct access to data in SQL format. This package consists primarily of classes that provide Java mappings to SQL data types and their support classes. Essentially, the classes act as Java containers for SQL data.
- Oracle Character Data Types Support
- Additional Oracle Type Extensions

4.2.3 Support for Oracle Objects

Oracle JDBC supports the use of structured objects in the database, where an object data type is a user-defined type with nested attributes. For example, a user application could define an `Employee` object type, where each `Employee` object has a `firstname` attribute (character string), a `lastname` attribute (character string), and an `employeenumber` attribute (integer).

Oracle JDBC supports Oracle object data types. When you work with Oracle object data types in a Java application, you must consider the following:

- How to map between Oracle object data types and Java classes
- How to store Oracle object attributes in corresponding Java objects
- How to convert attribute data between SQL and Java formats
- How to access data

Oracle objects can be mapped either to the weak `java.sql.Struct` type or to strongly typed customized classes. These strong types are referred to as custom Java classes, which must implement either the standard `java.sql.SQLData` interface or the Oracle extension `oracle.jdbc.OracleData` interface. Each interface specifies methods to convert data between SQL and Java.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `OracleData` interface has replaced the `ORAData` interface.

Oracle recommends the use of the Oracle JVM Web Service Call-Out Utility to create custom Java classes to correspond to your Oracle objects.

Related Topics

- Working with Oracle Object Types
- *Oracle AI Database Java Developer's Guide*

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4.2.4 Support for Schema Naming

Oracle object data type classes have the ability to accept and return fully qualified schema names. A fully qualified schema name has this syntax:

```
{[schema_name].}[sql_type_name]
```

Where, *schema_name* is the name of the schema and *sql_type_name* is the SQL type name of the object. *schema_name* and *sql_type_name* are separated by a period (.).

To specify an object type in JDBC, use its fully qualified name. It is not necessary to enter a schema name if the type name is in the current naming space, that is, the current schema. Schema naming follows these rules:

- Both the schema name and the type name may or may not be within quotation marks. However, if the SQL type name has a period in it, such as `CORPORATE.EMPLOYEE`, the type name must be quoted.
- The JDBC driver looks for the first period in the object name that is not within quotation marks and uses the string before the period as the schema name and the string following the period as the type name. If no period is found, then the JDBC driver takes the current schema as default. That is, you can specify only the type name, without indicating a schema, instead of specifying the fully qualified name if the object type name belongs to the current schema. This also explains why you must put the type name within quotation marks if the type name has a dot in it.

  For example, assume that user `HR` creates a type called `person.address` and then wants to use it in their session. `HR` may want to skip the schema name and pass in `person.address` to the JDBC driver. In this case, if `person.address` is not within quotation marks, then the period is detected and the JDBC driver mistakenly interprets `person` as the schema name and `address` as the type name.
- JDBC passes the object type name string to the database unchanged. That is, the JDBC driver does not change the character case even if the object type name is within quotation marks.

  For example, if `HR.PersonType` is passed to the JDBC driver as an object type name, then the JDBC driver passes the string to the database unchanged. As another example, if there is white space between characters in the type name string, then the JDBC driver will not remove the white space.

4.2.5 DML Returning

Oracle Database supports the use of the `RETURNING` clause with data manipulation language (DML) statements. This enables you to combine two SQL statements into one. Both the Oracle JDBC Oracle Call Interface (OCI) driver and the Oracle JDBC Thin driver support DML returning.

> **See Also**
>
> "DML Returning"

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4.2.6 PL/SQL Associative Arrays

Oracle JDBC drivers enable JDBC applications to make PL/SQL calls with Associative Array parameters. Oracle JDBC drivers support PL/SQL Associative Arrays of scalar data types

> **See Also**
>
> "Accessing PL/SQL Associative Arrays"

4.3 Oracle JDBC Packages

This section describes the following Java packages, which support the Oracle JDBC extensions:

- Package oracle.sql
- Package oracle.sql.json
- Package oracle.jdbc

4.3.1 Package oracle.sql

The `oracle.sql` package supports direct access to data in SQL format. This package consists primarily of classes that provide Java mappings to SQL data types and their support classes. Essentially, the classes act as Java containers for SQL data.

Each of the `oracle.sql.*` data type classes extends `oracle.sql.Datum`, a superclass that encapsulates functionality common to all the data types. Some of the classes are for JDBC 2.0-compliant data types. These classes, implement standard JDBC 2.0 interfaces in the `java.sql` package, as well as extending the `oracle.sql.Datum` class.

The `LONG` and `LONG RAW` SQL types and `REF CURSOR` type category have no `oracle.sql.*` classes. Use standard JDBC functionality for these types. For example, retrieve `LONG` or `LONG RAW` data as input streams using the standard JDBC result set and callable statement methods `getBinaryStream` and `getCharacterStream`. Use the `getCursor` method for `REF CURSOR` types.

> **Note**
>
> Oracle recommends the use of standard JDBC types or Java types whenever possible. The types in the package `oracle.sql.*` are provided primarily for backward compatibility or for support of a few Oracle specific features such as `OPAQUE`, `OracleData`, `TIMESTAMPTZ`, and so on.

General oracle.sql.* Data Type Support

Each of the Oracle data type classes provides, among other things, the following:

- Data storage as Java byte arrays for SQL data
- A `getBytes()` method, which returns the SQL data as a byte array
- A `toJdbc()` method that converts the data into an object of a corresponding Java class as defined in the JDBC specification

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The JDBC driver does not convert Oracle-specific data types that are not part of the JDBC specification, such as `BFILE`. The driver returns the object in the corresponding `oracle.sql.*` format.

- Appropriate *xxx*`Value` methods to convert SQL data to Java type. For example, `stringValue`, `intValue`, `booleanValue`, `dateValue`, and `bigDecimalValue`
- Additional conversion methods, `get`*XXX* and `set`*XXX*, as appropriate, for the functionality of the data type, such as methods in the large object (LOB) classes that get the data as a stream and methods in the `REF` class that get and set object data through the object reference.

Overview of Class oracle.sql.STRUCT

`oracle.sql.STRUCT` class is the Oracle implementation of `java.sql.Struct` interface. This class is a value class and you should not change the contents of the class after construction. This class, as with all `oracle.sql.*` data type classes, is a subclass of the `oracle.sql.Datum` class.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.STRUCT` class is deprecated and replaced with the `oracle.jdbc.OracleStruct` interface, which is a part of the `oracle.jdbc` package. Oracle strongly recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleStruct` interface.

Overview of Class oracle.sql.REF

The `oracle.sql.REF` class is the generic class that supports Oracle object references. This class, as with all `oracle.sql.*` data type classes, is a subclass of the `oracle.sql.Datum` class.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.REF` class is deprecated and replaced with the `oracle.jdbc.OracleRef` interface, which is a part of the `oracle.jdbc` package. Oracle strongly recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleRef` interface.

The `REF` class has methods to retrieve and pass object references. However, selecting an object reference retrieves only a pointer to an object. This does not materialize the object itself. But the `REF` class also includes methods to retrieve and pass the object data. You cannot create `REF` objects in your JDBC application. You can only retrieve existing `REF` objects from the database.

You should use the JDBC standard type, `java.sql.Ref`, and the JDBC standard methods in preference to using `oracle.sql.REF`. If you want your code to be more portable, then you must

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use the standard type because only the Oracle JDBC drivers will use instances of `oracle.sql.REF` type.

Overview of Classes oracle.sql.BLOB, oracle.sql.CLOB, oracle.sql.BFILE

Binary large objects (BLOBs), character large objects (CLOBs), and binary files (BFILEs) are for data items that are too large to store directly in a database table. Instead, the database table stores a locator that points to the location of the actual data.

> **Note**
>
> - Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.BLOB` and `Oracle.sql.CLOB` classes are deprecated and replaced with the `oracle.jdbc.OracleBlob` and `oracle.jdbc.OracleClob` interfaces respectively, which are a part of the `oracle.jdbc` package. Oracle strongly recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleBlob` and `oracle.jdbc.OracleClob` interfaces.
> - `oracle.sql.BFILE` is an Oracle proprietary extension and there is no JDBC standard equivalent.

The `oracle.sql` package supports these data types in several ways:

- BLOBs point to large unstructured binary data items and are supported by the `oracle.sql.BLOB` class.
- CLOBs point to large character data items and are supported by the `oracle.sql.CLOB` class.
- BFILEs point to the content of external files (operating system files) and are supported by the `oracle.sql.BFILE` class. BFiles are read-only.

You can select a BLOB, CLOB, or BFILE locator from the database using a standard `SELECT` statement. However, you receive only the locator, and not the data. Additional steps are necessary to retrieve the data.

Overview of Classes oracle.sql.DATE, oracle.sql.NUMBER, and oracle.sql.RAW

These classes hold primitive SQL data types in Oracle native representation. In most cases, these types are not used internally by the drivers and you should use the standard JDBC types instead.

Java `Double` and `Float` `NaN` values do not have an equivalent Oracle `NUMBER` representation. For example, for Oracle `BINARY_FLOAT` and `BINARY_DOUBLE` data types, negative zero is coerced to positive zero and all NaNs are coerced to the canonical one. So, a `NullPointerException` is thrown whenever a `Double.NaN` value or a `Float.NaN` value is converted into an Oracle `NUMBER` using the `oracle.sql.NUMBER` class. For instance, the following code throws a `NullPointerException`:

```
oracle.sql.NUMBER n = new oracle.sql.NUMBER(Double.NaN);
System.out.println(n.doubleValue());  // throws NullPointerException
```

Overview of Classes oracle.sql.TIMESTAMP, oracle.sql.TIMESTAMPTZ, and oracle.sql.TIMESTAMPLTZ

The JDBC drivers support the following date/time data types:

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- `TIMESTAMP` (`TIMESTAMP`)
- `TIMESTAMP WITH TIME ZONE` (`TIMESTAMPTZ`)
- `TIMESTAMP WITH LOCAL TIME ZONE` (`TIMESTAMPLTZ`)

The JDBC drivers allow conversions between `DATE` and date/time data types. For example, you can access a `TIMESTAMP WITH TIME ZONE` column as a `DATE` value.

The JDBC drivers support the most popular time zone names used in the industry as well as most of the time zone names defined in the JDK. Time zones are specified by using the `java.util.TimeZone` class.

> **Note**
>
> - Do not use `TimeZone.getTimeZone` to create time zone objects. The Oracle time zone data types support more time zone names than JDK.
> - If a result set contains a `TIMESTAMPLTZ` column followed by a `LONG` column, then reading the `LONG` column results in an error.

The following code shows how the `TimeZone` and `Calendar` objects are created for `US_PACIFIC`, which is a time zone name not defined in JDK:

```
TimeZone tz = TimeZone.getDefault();
tz.setID("US_PACIFIC");
GregorianCalendar gcal = new GregorianCalendar(tz);
```

The following Java classes represent the SQL date/time types:

- `oracle.sql.TIMESTAMP`
- `oracle.sql.TIMESTAMPTZ`
- `oracle.sql.TIMESTAMPLTZ`

Before accessing `TIMESTAMP WITH LOCAL TIME ZONE` data, call the `OracleConnection.setSessionTimeZone(String regionName)` method to set the session time zone. When this method is called, the JDBC driver sets the session time zone of the connection and saves the session time zone so that any `TIMESTAMP WITH LOCAL TIME ZONE` data accessed through JDBC can be adjusted using the session time zone.

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> **Note**
>
> `TIMESTAMP WITH TIME ZONE` and `TIMESTAMP WITH LOCAL TIME ZONE` types can be represented as standard `java.sql.Timestamp` type. The byte representation of `TIMESTAMP WITH TIME ZONE` and `TIMESTAMP WITH LOCAL TIME ZONE` types to `java.sql.Timestamp` is straight forward. This is because the internal format of `TIMESTAMP WITH TIME ZONE` and `TIMESTAMP WITH LOCAL TIME ZONE` data types is GMT, and `java.sql.Timestamp` type objects internally use a milliseconds time value that is the number of milliseconds since EPOCH. However, the `String` representation of these data types requires time zone information that is obtained dynamically from the server and cached on the client side.
>
> In earlier versions of JDBC drivers, the cache of time zone was shared across different connections. This used to cause problems sometimes due to incompatibility in various time zones. Starting from Oracle Database 11 Release 2 version of JDBC drivers, the time zone cache is based on the time zone version supplied by the database. This newly designed cache avoids any issues related to version incompatibility of time zones.

Overview of Class oracle.sql.OPAQUE

The `oracle.sql.OPAQUE` class provides the name and characteristics of the `OPAQUE` type and any attributes. The `OPAQUE` type provides access only to the uninterrupted bytes of the instance.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.OPAQUE` class is deprecated and replaced with the `oracle.jdbc.OracleOpaque` interface, which is a part of the `oracle.jdbc` package. Oracle recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleOpaque` interface.

Related Topics

- *Oracle AI Database SQL Language Reference*
- Working with Large Objects and SecureFiles
  Large Objects (LOBs) are a set of data types that are designed to hold large amounts of data. This chapter describes how to use Java Database Connectivity (JDBC) to access and manipulate LOBs and SecureFiles using either the data interface or the locator interface.

4.3.2 Package oracle.sql.json

Starting with release 21c, Oracle Database provides a native JSON SQL type in the database. The `oracle.sql.json` package provides functionality to work with the JSON type values.

Specifically, you can use the `oracle.sql.json` package to perform the following tasks:

- Store and retrieve JSON type values in the database

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- Read, create, and modify JSON type values
- Encode or decode JSON type values in the same binary JSON storage format as used by the database
- Convert JSON type values to and from JSON text
- Bind and access JSON type values using the JSON-P interfaces like `javax.json.*`

> **See Also**
>
> JDBC Java API Reference

The following example shows how to insert, get, and modify JSON type values:

```
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;

import oracle.jdbc.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;
import oracle.sql.json.OracleJsonFactory;
import oracle.sql.json.OracleJsonObject;

public class JsonExample {

  public static void main(String[] args) throws SQLException {
    OracleDataSource ds = new OracleDataSource();
    ds.setURL("jdbc:oracle:thin:@myhost:1521:orcl");
    ds.setUser(<user>);
    ds.setPassword(<password>);
    OracleConnection con = (OracleConnection) ds.getConnection();

    // create a table with a JSON column and insert one value
    Statement stmt = con.createStatement();
    stmt.executeUpdate("CREATE TABLE fruit (data JSON)");
    stmt.executeUpdate("INSERT INTO fruit VALUES
('{"name":"pear","count":10}')");

    // create another JSON object
    OracleJsonFactory factory = new OracleJsonFactory();
    OracleJsonObject orange = factory.createObject();
    orange.put("name", "orange");
    orange.put("count", 12);

    // insert the orange object
    PreparedStatement pstmt = con.prepareStatement("INSERT INTO fruit VALUES
(:1)");
    pstmt.setObject(1, orange, OracleType.JSON);
    pstmt.executeUpdate();
    pstmt.close();

    // retrieve the pear object
    ResultSet rs = stmt.executeQuery("SELECT data FROM fruit f WHERE
f.data.name = 'pear'");
```


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```
    rs.next();
    OracleJsonObject pear = rs.getObject(1, OracleJsonObject.class);
    int count = pear.getInt("count");

    // create a modifiable copy of the pear object
    pear = factory.createObject(pear);
    pear.put("count", count + 1);
    pear.put("color", "green");

    // update the pear object
    pstmt = con.prepareStatement("UPDATE fruit f SET data = :1 WHERE
f.data.name = 'pear');
    pstmt.setObject(1, pear, OracleType.JSON);
    pstmt.executeUpdate();
    pstmt.close();

    rs.close();
    stmt.close();
    con.close();
  }
}
```

Compatibility with Client Libraries Prior to Release 21c

If you have a client library earlier to release 21c, then your application treats the JSON type column in the database as a String, BLOB, or CLOB column. So, to query the JSON type column, you must use the query methods for those data types. However, when you use the BLOB APIs like the `getBlob` method, they return an error, even after you upgrade the client library. So, Oracle recommends that for BLOB data type, you use the `getBytes` method or the `getBinaryStream` method, which will return text data with UTF-8 JSON encoding. The following code snippets show how to query a JSON type column for BLOB data type:

Example: Using the `getBinaryStream` Method

```
public static void fetchStream(ResultSet rs) throws SQLException, IOException
{
  InputStream is = rs.getBinaryStream("JCOL");
  ByteArrayOutputStream baos = new ByteArrayOutputStream();
  int n = -1;
  byte[] buffer = new byte[1024];
  while ((n = is.read(buffer)) != -1) {
    baos.write(buffer, 0, n);
  }
  is.close();
  byte[] bytes = baos.toByteArray();
  System.out.println(new String(bytes, StandardCharsets.UTF_8));
}
public static void example1(Connection con) throws SQLException, IOException
{
  Statement stmt = con.createStatement();

  ResultSet rs = stmt.executeQuery("select jcol from jtab where rownum < 2");

  while (rs.next()){
    fetchStream(rs);
```


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```
  }
}
```

Example: Using the `getBytes` Method

```
public static void fetchString(ResultSet rs) throws SQLException
{
  byte[] utf8 = rs.getBytes("JCOL");

  System.out.println(new String(utf8, StandardCharsets.UTF_8));
}
public static void example2(Connection con) throws SQLException
{
  Statement stmt = con.createStatement();

  ResultSet rs = stmt.executeQuery("select jcol from jtab where rownum < 2");

  while (rs.next()){
    fetchString(rs);
  }
}
```

Support for Array Enqueue and Dequeue of JSON Payload Type

Oracle Database 21c release introduced support for JSON payload type in Oracle Advance Queuing (AQ). For example, when you create a queue in the database, you can mention the queue payload type in the following way:

```
BEGIN

    DBMS_AQADM.CREATE_QUEUE_TABLE(

            QUEUE_TABLE =>'HR.JSON_SINGLE_QUEUE_TABLE',

            QUEUE_PAYLOAD_TYPE =>'JSON',

            COMPATIBLE => '10.0');

END;
```

Once you create a JSON payload type queue in the database, you can enqueue and dequeue JSON messages to/from that queue.

Starting from Oracle Database 23ai release, the driver supports the array enqueue and dequeue of JSON messages, which means that the client applications can enqueue and dequeue more than one JSON type messages to/from the database.

> **See Also**
>
> Oracle Advanced Queuing for more information about AQ

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4.3.3 Package oracle.jdbc

The interfaces of the `oracle.jdbc` package define the Oracle extensions to the interfaces in `java.sql`. These extensions provide access to Oracle SQL-format data and other Oracle-specific functionality, including Oracle performance enhancements.

> **See Also**
>
> "The oracle.jdbc Package"

4.4 Oracle Character Data Types Support

Oracle character data types include the SQL CHAR and NCHAR data types. The following sections describe how these data types can be accessed using the `oracle.sql.*` classes:

- SQL CHAR Data Types
- SQL NCHAR Data Types
- Class oracle.sql.CHAR

4.4.1 SQL CHAR Data Types

The SQL CHAR data types include `CHAR`, `VARCHAR2`, and `CLOB`. These data types let you store character data in the database character set encoding scheme. The character set of the database is established when you create the database.

4.4.2 SQL NCHAR Data Types

The SQL `NCHAR` data types were created for Globalization Support. The SQL `NCHAR` data types include `NCHAR`, `NVARCHAR2`, and `NCLOB`. These data types enable you to store Unicode data in the database `NCHAR` character set encoding. The `NCHAR` character set, which never changes, is established when you create the database.

> **Note**
>
> Because the `UnicodeStream` class is deprecated in favor of the `CharacterStream` class, the `setUnicodeStream` and `getUnicodeStream` methods are not supported for `NCHAR` data type access. Use the `setCharacterStream` method and the `getCharacterStream` method if you want to use stream access.

The usage of SQL `NCHAR` data types is similar to that of the SQL `CHAR` data types. JDBC uses the same classes and methods to access SQL `NCHAR` data types that are used for the corresponding SQL `CHAR` data types. Therefore, there are no separate, corresponding classes defined in the `oracle.sql` package for SQL `NCHAR` data types. Similarly, there is no separate, corresponding constant defined in the `oracle.jdbc.OracleTypes` class for SQL `NCHAR` data types.

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> **See Also**
>
> "NCHAR_ NVARCHAR2_ NCLOB and the defaultNChar Property"

> **Note**
>
> The `setFormOfUse` method must be called before the `registerOutParameter` method is called in order to avoid unpredictable results.

The following code shows how to access SQL `NCHAR` data:

```
//
// Table TEST has the following columns:
// - NUMBER
// - NVARCHAR2
// - NCHAR
//
oracle.jdbc.OraclePreparedStatement pstmt =
  (oracle.jdbc.OraclePreparedStatement)
conn.prepareStatement("insert into TEST values(?, ?, ?)");

//
// oracle.jdbc.OraclePreparedStatement.FORM_NCHAR should be used for all NCHAR,
// NVARCHAR2 and NCLOB data types.
//

pstmt.setInt(1, 1);                    // NUMBER column
pstmt.setNString(2, myUnicodeString1);  // NVARCHAR2 column
pstmt.setNString(3, myUnicodeString2);  // NCHAR column
pstmt.execute();
```

4.4.3 Class oracle.sql.CHAR

The `oracle.sql.CHAR` class is used by Oracle JDBC in handling and converting character data. This class provides the Globalization Support functionality to convert character data. This class has two key attributes: Globalization Support character set and the character data. The Globalization Support character set defines the encoding of the character data. It is a parameter that is always passed when a `CHAR` object is constructed. Without the Globalization Support character set information, the data bytes in the `CHAR` object are meaningless. The `oracle.sql.CHAR` class is used for both SQL `CHAR` and SQL `NCHAR` data types.

> **Note**
>
> In versions of Oracle JDBC drivers prior to 10*g* Release 1, there were performance advantages to using the `oracle.SQL.CHAR`. Starting from Oracle Database 10*g*, there are no longer any such advantages. In fact, optimum performance is achieved using the `java.lang.String`. All Oracle JDBC drivers handle all character data in the Java UCS2 character set. Using the `oracle.sql.CHAR` does not prevent conversions between the database character set and UCS2 character set.

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The only remaining use of the `oracle.sql.CHAR` class is to handle character data in the form of raw bytes encoded in an Oracle Globalization Support character set. All character data retrieved from Oracle Database should be accessed using the `java.lang.String` class. When processing byte data from another source, you can use an `oracle.sql.CHAR` to convert the bytes to `java.lang.String`.

To convert an `oracle.sql.CHAR`, you must provide the data bytes and an `oracle.sql.CharacterSet` instance that represents the Globalization Support character set used to encode the data bytes.

The `CHAR` objects that are Oracle object attributes are returned in the database character set.

JDBC application code rarely needs to construct `CHAR` objects directly, because the JDBC driver automatically creates `CHAR` objects, when it is needed to create them on those rare occasions.

To construct a `CHAR` object, you must provide character set information to the `CHAR` object by way of an instance of the `CharacterSet` class. Each instance of this class represents one of the Globalization Support character sets that Oracle supports. A `CharacterSet` instance encapsulates methods and attributes of the character set, mainly involving functionality to convert to or from other character sets.

Constructing an oracle.sql.CHAR Object

Follow these general steps to construct a `CHAR` object:

1. Create a `CharacterSet` object by calling the `static CharacterSet.make` method.

   This method is a factory for the character set instance. The `make` method takes an integer as input, which corresponds to a character set ID that Oracle supports. For example:

   ```
   int oracleId = CharacterSet.JA16SJIS_CHARSET; // this is character set ID,
                                                 // 832
   ...
   CharacterSet mycharset = CharacterSet.make(oracleId);
   ```

   Each character set that Oracle supports has a unique, predefined Oracle ID.

2. Construct a `CHAR` object.

   Pass a string, or the bytes that represent the string, to the constructor along with the `CharacterSet` object that indicates how to interpret the bytes based on the character set. For example:

   ```
   String mystring = "teststring";
   ...
   CHAR mychar = new CHAR(teststring, mycharset);
   ```

   There are multiple constructors for `CHAR`, which can take a `String`, a `byte` array, or an object as input along with the `CharacterSet` object. In the case of a `String`, the string is converted to the character set indicated by the `CharacterSet` object before being placed into the `CHAR` object.

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> **Note**
>
> - The `CharacterSet` object cannot be a null value.
> - The `CharacterSet` class is an abstract class, therefore it has no constructor. The only way to create instances is to use the `make` method.
> - The server recognizes the special value `CharacterSet.DEFAULT_CHARSET` as the database character set. For the client, this value is not meaningful.
> - Oracle does not intend or recommend that users extend the `CharacterSet` class.

oracle.sql.CHAR Conversion Methods

The `CHAR` class provides the following methods for translating character data to strings:

- `getString`

  This method converts the sequence of characters represented by the `CHAR` object to a string, returning a Java `String` object. If you enter an invalid `OracleID`, then the character set will not be recognized and the `getString` method will throw a `SQLException` exception.

- `toString`

  This method is identical to the `getString` method. But if you enter an invalid `OracleID`, then the character set will not be recognized and the `toString` method will return a hexadecimal representation of the `CHAR` data and will *not* throw a `SQLException` exception.

- `getStringWithReplacement`

  This method is identical to the `getString` method, except a default replacement character replaces characters that have no unicode representation in the `CHAR` object character set. This default character varies from character set to character set, but is often a question mark (?).

The database server and the client, or application running on the client, can use different character sets. When you use the methods of the `CHAR` class to transfer data between the server and the client, the JDBC drivers must convert the data from the server character set to the client character set or vice versa. To convert the data, the drivers use Globalization Support.

> **See Also**
>
> Globalization Support

4.5 Additional Oracle Type Extensions

Oracle JDBC drivers support the Oracle-specific `BFILE` and `ROWID` data types and `REF CURSOR` types, which are not part of the standard JDBC specification. This section describes the `ROWID` and `REF CURSOR` type extensions. The `ROWID` is supported as a Java string, and `REF CURSOR` types are supported as JDBC result sets.

This section covers the following topics:

- Oracle ROWID Type

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- Oracle REF CURSOR Type Category
- Oracle BINARY_FLOAT and BINARY_DOUBLE Types
- Oracle SYS.ANYTYPE and SYS.ANYDATA Types
- The oracle.jdbc Package

4.5.1 Oracle ROWID Type

A ROWID is an identification tag unique for each row of an Oracle Database table. The ROWID can be thought of as a virtual column, containing the ID for each row.

The `oracle.sql.ROWID` class is supplied as a container for `ROWID` SQL data type.

ROWIDs provide functionality similar to the `getCursorName` method specified in the `java.sql.ResultSet` interface and the `setCursorName` method specified in the `java.sql.Statement` interface.

If you include the ROWID pseudo-column in a query, then you can retrieve the ROWIDs with the result set `getString` method. You can also bind a ROWID to a `PreparedStatement` parameter with the `setString` method. This enables in-place updating, as in the example that follows.

> **Note**
>
> Use the `oracle.sql.ROWID` class, only when you are using J2SE 5.0. For JSE 6, you should use the standard `java.sql.RowId` interface instead.

Example

The following example shows how to access and manipulate ROWID data:

> **Note**
>
> The following example works only with JSE 6.

```
Statement stmt = conn.createStatement();

// Query the employee names with "FOR UPDATE" to lock the rows.
// Select the ROWID to identify the rows to be updated.

ResultSet rset =
   stmt.executeQuery ("SELECT first_name, rowid FROM employees FOR UPDATE");

// Prepare a statement to update the first_name column at a given ROWID

PreparedStatement pstmt =
   conn.prepareStatement ("UPDATE employees SET first_name = ? WHERE rowid = ?");

// Loop through the results of the query
while (rset.next ())
{
    String ename = rset.getString (1);
 RowId rowid = rset.getROWID(2); // Get the ROWID as a String
```


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```
    pstmt.setString (1, ename.toLowerCase ());
    pstmt.setROWID (2, rowid); // Pass ROWID to the update statement
    pstmt.executeUpdate ();     // Do the update
}
```

4.5.2 Oracle REF CURSOR Type Category

A cursor variable holds the memory location of a query work area, rather than the contents of the area. Declaring a cursor variable creates a pointer. In SQL, a pointer has the data type `REF x`, where `REF` is short for `REFERENCE` and *x* represents the entity being referenced. A `REF CURSOR`, then, identifies a reference to a cursor variable. Because many cursor variables might exist to point to many work areas, `REF CURSOR` can be thought of as a category or data type specifier that identifies many different types of cursor variables. Starting from Oracle Database Release 18 *c*, JDBC drivers support `REF CURSOR` as IN bind variables.

> **Note**
>
> `REF CURSOR` instances are not scrollable.

Perform the following steps to create a cursor variable:

1. Identify a type that belongs to the `REF CURSOR` category. For example:

   ```
   DECLARE TYPE DeptCursorTyp IS REF CURSOR
   ```

2. Then, create the cursor variable by declaring it to be of the type `DeptCursorTyp`:

   ```
   dept_cv DeptCursorTyp  - - declare cursor variable
   ...
   ```

   `REF CURSOR`, then, is a category of data types, rather than a particular data type.

Stored procedures can accept or return cursor variables of the `REF CURSOR` category. This output is equivalent to a database cursor or a JDBC result set. A `REF CURSOR` essentially encapsulates the results of a query.

In JDBC, a `REF CURSOR` can be accessed as follows:

1. Use a JDBC callable statement or a prepared statement to call a stored procedure.
2. The stored procedure accepts or returns a `REF CURSOR`.
3. The Java application casts the callable statement or prepared statement to an Oracle callable statement or Oracle prepared statement.
4. The Java application uses the `setCursor` method of the `OraclePreparedStatement` interface or the `getCursor` method of the `OracleCallableStatement` interface to materialize the `REF CURSOR` as a JDBC `ResultSet` object.
5. The result set is processed as requested.

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> **Note**
>
> - The cursor associated with a `REF CURSOR` is closed whenever the statement object that produced the `REF CURSOR` is closed.
> - Unlike in past releases, the cursor associated with a `REF CURSOR` is *not* closed when the result set object in which the `REF CURSOR` was materialized is closed.

Example

This example shows how to access `REF CURSOR` data.

```
    ...
    // Prepare a PL/SQL call
    CallableStatement cstmt =
      conn.prepareCall ("DECLARE  rc sys_refcursor; curid NUMBER;BEGIN open
rc FOR SELECT empno FROM emp order by empno; ? := rc;  END;");

    cstmt.registerOutParameter (1, OracleTypes.CURSOR);
    cstmt.execute ();
    ResultSet rset = (ResultSet)cstmt.getObject (1);

    if (rset.next ()) {
      show (rset.getString ("empno"));
    }

    CallableStatement cstmt2 =
      conn.prepareCall ("DECLARE  rc sys_refcursor; v1 NUMBER; BEGIN rc := ?;
fetch rc INTO v1; ? := v1; END;");
    ((OracleCallableStatement)call2).setCursor(1, rset);
    cstmt2.registerOutParameter (2, OracleTypes.INTEGER);

    cstmt2.execute();

    int empno = cstmt2.getInt(2);

    show("Fetch in PL/SQL empno=" + empno);

    // Dump the cursor
    while (rset.next ())
      show (rset.getString ("empno"));

    // Close all the resources
    rset.close();
    cstmt.close();
    cstmt2.close();
  ...
```

In the preceding example:

- Two `CallableStatement` objects `cstmt1` and `cstmt2` are created using the `prepareCall` method of the `Connection` class.
- The `cstmt2` callable statement uses `REF CURSOR` as input parameter.

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- The callable statements implement PL/SQL procedure that returns a `REF CURSOR`.
- As always, the output parameter of the callable statement must be registered to define its type. Use the type code `OracleTypes.CURSOR` for a `REF CURSOR`.
- The callable statements are run, returning the `REF CURSOR` or sending the `REF CURSOR` as input bind.

4.5.3 Oracle BINARY_FLOAT and BINARY_DOUBLE Types

The Oracle `BINARY_FLOAT` and `BINARY_DOUBLE` types are used to store IEEE 574 float and double data. These correspond to the Java `float` and `double` scalar types with the exception of negative zero and `NaN`.

> **See Also**
>
> *Oracle Database SQL Language Reference*

If you include a `BINARY_DOUBLE` column in a query, then the data is retrieved from the database in the binary format. Also, the `getDouble` method will return the data in the binary format. In contrast, for a `NUMBER` data type column, the number bits are returned and converted to the Java `double` data type.

> **Note**
>
> The Oracle representation for the SQL `FLOAT`, `DOUBLE PRECISION`, and `REAL` data types use the Oracle `NUMBER` representation. The `BINARY_FLOAT` and `BINARY_DOUBLE` data types can be regarded as proprietary types.

A call to the JDBC standard `setDouble(int, double)` method of the `PreparedStatement` interface converts the Java `double` argument to Oracle `NUMBER` style bits and send them to the database. In contrast, the `setBinaryDouble(int, double)` method of the `oracle.jdbc.OraclePreparedStatement` interface converts the data to the internal binary bits and sends them to the database.

You must ensure that the data format used matches the type of the target parameter of the `PreparedStatement` interface. This will result in correct data and least use of CPU. If you use `setBinaryDouble` for a `NUMBER` parameter, then the binary bits are sent to the server and converted to `NUMBER` format. The data will be correct, but server CPU load will be increased. If you use `setDouble` for a `BINARY_DOUBLE` parameter, then the data will first be converted to `NUMBER` bits on the client and sent to the server, where it will be converted back to binary format. This will increase the CPU load on both client and server and can result in data corruption as well.

The `SetFloatAndDoubleUseBinary` connection property when set to `true` causes the JDBC standard APIs, `setFloat(int, float)`, `setDouble(int, double)`, and all the variations, to send internal binary bits instead of `NUBMER` bits.

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> **Note**
>
> Although this section largely discusses `BINARY_DOUBLE`, the same is true for `BINARY_FLOAT` as well.

4.5.4 Oracle SYS.ANYTYPE and SYS.ANYDATA Types

Oracle Database 12*c* Release 1 (12.1) provides a Java interface to access the `SYS.ANYTYPE` and `SYS.ANYDATA` Oracle types.

> **See Also**
>
> For information about these Oracle types, refer *Oracle AI Database PL/SQL Packages and Types Reference*

An instance of the `SYS.ANYTYPE` type contains a type description of any SQL type, persistent or transient, named or unnamed, including object types and collection types. You can use the `oracle.sql.TypeDescriptor` class to access the `SYS.ANYTYPE` type. An `ANYTYPE` instance can be retrieved from a PL/SQL procedure or a SQL `SELECT` statement where `SYS.ANYTYPE` is used as a column type. To retrieve an `ANYTYPE` instance from the database, use the `getObject` method. This method returns an instance of the `TypeDescriptor`.

The retrieved `ANYTYPE` instance could be any of the following:

- Transient object type
- Transient predefined type
- Persistent object type
- Persistent predefined type

Example 4-1 Accessing SYS.ANYTYPE Type

The following code snippet illustrates how to retrieve an instance of `ANYTYPE` from the database:

```
...
ResultSet rs = stmt.executeQuery("select anytype_column from my_table");
TypeDescriptor td = (TypeDescriptor)rs.getObject(1);
short typeCode = td.getInternalTypeCode();
if(typeCode == TypeDescriptor.TYPECODE_OBJECT)
{
  // check if it's a transient type
  if(td.isTransientType())
  {
    AttributeDescriptor[] attributes = ((StructDescriptor)td).getAttributesDescriptor();
    for(int i=0; i<attributes.length; i++)
      System.out.println(attributes[i].getAttributeName());
  }
  else
  {    System.out.println(td.getTypeName());  }}
...
```


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Example 4-2 Creating a Transient Object Type Through PL/SQL and Retrieving Through JDBC

This example provides a code snippet illustrating how to retrieve a transient object type through JDBC.

```
...
OracleCallableStatement cstmt = (OracleCallableStatement)conn.prepareCall
  ("BEGIN ? := transient_obj_type (); END;");
cstmt.registerOutParameter(1,OracleTypes.OPAQUE,"SYS.ANYTYPE");
cstmt.execute();
TypeDescriptor obj = (TypeDescriptor)cstmt.getObject(1);
if(!obj.isTransient())
  System.out.println("This must be a JDBC bug");
cstmt.close();
return obj;
...
```

Example 4-3 Calling a PL/SQL Stored Procedure That Takes an ANYTPE as IN Parameter

The following code snippet illustrates how to call a PL/SQL stored procedure that takes an `ANYTYPE` as `IN` parameter:

```
...
CallableStatement cstmt = conn.prepareCall("BEGIN ? := dumpanytype(?); END;");
cstmt.registerOutParameter(1,OracleTypes.VARCHAR);
// obj is the instance of TypeDescriptor that you have retrieved
cstmt.setObject(2,obj);
cstmt.execute();
String str = (String)cstmt.getObject(1);
...
```

The `oracle.sql.ANYDATA` class enables you to access `SYS.ANYDATA` instances from the database. An instance of this class can be obtained from any valid instance of `oracle.sql.Datum` class. The `convertDatum` factory method takes an instance of `Datum` and returns an instance of `ANYDATA`. The syntax for this factory method is as follows:

```
public static ANYDATA convertDatum(Datum datum) throws SQLException
```

The following is sample code for creating an instance of `oracle.sql.ANYDATA`:

```
// struct is a valid instance of oracle.sql.STRUCT that either comes from the
// database or has been constructed in Java.
ANYDATA myAnyData = ANYDATA.convertDatum(struct);
```

Example 4-4 Accessing an Instance of ANYDATA from the Database

```
...
// anydata_table has been created as:
// CREATE TABLE anydata_tab (data SYS.ANYDATA)
Statement stmt = conn.createStatement();
ResultSet rs = stmt.executeQuery("select data from my_anydata_tab");
while(rs.next())
{
  ANYDATA anydata = (ANYDATA)rs.getObject(1);
  if(!anydata.isNull())
  {
    TypeDescriptor td = anydata.getTypeDescriptor();
    if(td.getTypeCode() == OracleType.TYPECODE_OBJECT)
      STRUCT struct = (STRUCT)anydata.accessDatum();
  }
```


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```
}
...
```

Example 4-5 Inserting an Object as ANYDATA in a Database Table

Consider the following table and object type definition:

```
CREATE TABLE anydata_tab ( id NUMBER, data SYS.ANYDATA)

CREATE OR REPLACE TYPE employee AS OBJECT ( employee_id NUMBER, first_name VARCHAR2(10) )
```

You can create an instance of the `EMPLOYEE` SQL object type and to insert it into `anydata_table` in the following way:

```
...
PreparedStatement pstmt = conn.prepareStatement("insert into anydata_table values
(?,?)");
Struct myEmployeeStr = conn.createStruct("EMPLOYEE", new Object[]{1120, "Papageno"});
ANYDATA anyda = ANYDATA.convertDatum(myEmployeeStr);
pstmt.setInt(1,123);
pstmt.setObject(2,anyda);
pstmt.executeUpdate();
...
```

Example 4-6 Selecting an ANYDATA Column from a Database Table

```
...
Statement stmt = conn.createStatement();
ResultSet rs = stmt.executeQuery("select data from anydata_table");
while(rs.next())
{
  ANYDATA obj = (ANYDATA)rs.getObject(1);
  TypeDescriptor td = obj.getTypeDescriptor();
}
rs.close();
stmt.close();
...
```

4.5.5 The oracle.jdbc Package

The interfaces of the `oracle.jdbc` package define the Oracle extensions to the interfaces in `java.sql`. These extensions provide access to SQL-format data as described in this chapter. They also provide access to other Oracle-specific functionality, including Oracle performance enhancements.

For the `oracle.jdbc` package, Table 4-1 lists key interfaces and classes used for connections, statements, and result sets.

Table 4-1 Key Interfaces and Classes of the oracle.jdbc Package

Name	Interface or Class	Key Functionality
`OracleDriver`	Class	Implements `java.sql.Driver`
`OracleConnection`	Interface	Provides methods to start and stop an Oracle Database instance and to return Oracle statement objects and methods to set Oracle performance extensions for any statement run in the current connection. Implements `java.sql.Connection.`

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Table 4-1 (Cont.) Key Interfaces and Classes of the oracle.jdbc Package

Name	Interface or Class	Key Functionality
`OracleStatement`	Interface	Provides methods to set Oracle performance extensions for individual statement. Is a supertype of `OraclePreparedStatement` and `OracleCallableStatement`. Implements `java.sql.Statement`.
`OraclePreparedStatement`	Interface	Provides `set`*XXX* methods to bind `oracle.sql.*` types into a prepared statement. Provides `getMetaData` method to get the metadata from the prepared statements without executing the SELECT statements. Implements `java.sql.PreparedStatement`. Extends `OracleStatement`. Is a supertype of `OracleCallableStatement`.
`OracleCallableStatement`	Interface	Provides `get`*XXX* methods to retrieve data in `oracle.sql` format and `set`*XXX* methods to bind `oracle.sql.*` types into a callable statement. Implements `java.sql.CallableStatement`. Extends `OraclePreparedStatement`.
`OracleResultSet`	Interface	Provides `get`*XXX* methods to retrieve data in `oracle.sql` format. Implements `java.sql.ResultSet`.
`OracleResultSetMetaData`	Interface	Provides methods to get metadata information about Oracle result sets, such as column names and data types. Implements `java.sql.ResultSetMetaData`.
`OracleDatabaseMetaData`	Class	Provides methods to get metadata information about the database, such as database product name and version, table information, and default transaction isolation level. Implements `java.sql.DatabaseMetaData`).
`OracleTypes`	Class	Defines integer constants used to identify SQL types. For standard types, it uses the same values as the standard `java.sql.Types` class. In addition, it adds constants for Oracle extended types.
`OracleArray`	Interface	Includes functionality to retrieve the array as a whole, retrieve a subset of the array elements, and retrieve the SQL base type name of the array elements.
`OracleStruct`	Interface	
`OracleClob`	Interface	
`OracleBlob`	Interface	
`OracleRef`	Interface	

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Table 4-1 (Cont.) Key Interfaces and Classes of the oracle.jdbc Package

Name	Interface or Class	Key Functionality
`OracleOpaque`	Interface	

This section covers the following topics:

- Interface oracle.jdbc.OracleConnection
- Interface oracle.jdbc.OracleStatement
- Interface oracle.jdbc.OraclePreparedStatement
- Interface oracle.jdbc.OracleCallableStatement
- Interface oracle.jdbc.OracleResultSet
- Interface oracle.jdbc.OracleResultSetMetaData
- Class oracle.jdbc.OracleTypes

4.5.5.1 Interface oracle.jdbc.OracleConnection

This interface extends standard JDBC connection functionality to create and return Oracle statement objects, set flags and options for Oracle performance extensions, support type maps for Oracle objects, and support client identifiers.

In Oracle Database 11*g* Release 1, new methods were added to this interface that enable the starting up and shutting down of an Oracle Database instance. Also, for better visibility and clarity, all connection properties are defined as constants in the `OracleConnection` interface.

This interface also defines factory methods for constructing `oracle.sql` data values like `DATE` and `NUMBER`. Remember the following points while using factory methods:

- All code that constructs instances of the `oracle.sql` types should use the Oracle extension factory methods. For example, `ARRAY`, `BFILE`, `DATE`, `INTERVALDS`, `NUMBER`, `STRUCT`, `TIME`, `TIMESTAMP`, and so on.
- All code that constructs instances of the standard types should use the JDBC 4.0 standard factory methods. For example, `CLOB`, `BLOB`, `NCLOB`, and so on.
- There are no factory methods for `CHAR`, `JAVA_STRUCT`, `ArrayDescriptor`, and `StructDescriptor`. These types are for internal driver use only.

> **Note**
>
> Prior to Oracle Database 11*g* Release 1, you had to construct `ArrayDescriptors` and `StructDescriptors` for passing as arguments to the `ARRAY` and `STRUCT` class constructors. The new `ARRAY` and `Struct` factory methods do not have any descriptor arguments. The driver still uses descriptors internally, but you do not need to create them.

Client Identifiers

In a connection pooling environment, the client identifier can be used to identify the lightweight user using the database session currently. A client identifier can also be used to share the

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Globally Accessed Application Context between different database sessions. The client identifier set in a database session is audited when database auditing is turned on.

> **See Also**
>
> *Oracle AI Database JDBC Java API Reference* for more information

4.5.5.2 Interface oracle.jdbc.OracleStatement

This interface extends standard JDBC statement functionality and is the superinterface of the `OraclePreparedStatement` and `OracleCallableStatement` classes. Extended functionality includes support for setting flags and options for Oracle performance extensions on a statement-by-statement basis, as opposed to the `OracleConnection` interface that sets these on a connectionwide basis.

4.5.5.3 Interface oracle.jdbc.OraclePreparedStatement

This interface extends the `OracleStatement` interface and extends standard JDBC prepared statement functionality. Also, the `oracle.jdbc.OraclePreparedStatement` interface is extended by the `OracleCallableStatement` interface. Extended functionality consists of the following:

- `set`*`XXX`* methods for binding `oracle.sql.*` types and objects to prepared statements
- `getMetaData` method to get the metadata from the prepared statements without executing the SELECT statements
- Methods to support Oracle performance extensions on a statement-by-statement basis

> **Note**
>
> Do not use the `PreparedStatement` interface to create a trigger that refers to a `:NEW` or `:OLD` column. Use `Statement` instead. Using `PreparedStatement` will cause execution to fail with the message `java.sql.SQLException: Missing IN or OUT parameter at index:: 1`.

4.5.5.4 Interface oracle.jdbc.OracleCallableStatement

This interface extends the `OraclePreparedStatement` interface, which extends the `OracleStatement` interface and incorporates standard JDBC callable statement functionality.

> **Note**
>
> Do not use the `CallableStatement` interface to create a trigger that refers to a `:NEW` or `:OLD` column. Use `Statement` instead; using `CallableStatement` will cause execution to fail with the message `java.sql.SQLException: Missing IN or OUT parameter at index::1`

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> **Note**
>
> - The `set`*`XXX`*`(String,...)` and `registerOutParameter(String,...)` methods can be used only if all binds are procedure or function parameters only. The statement can contain no other binds and the parameter binds must be indicated with a question mark (`?`) and not `:`*`XX`*.
> - If you are using `set`*`XXX`*`(int,...) or set`*`XXX`*`AtName(String,...)` method, then any output parameter is bound with `registerOutParameter(int,...)` and not `registerOutParameter(String,...)`, which is for named parameter notation.

4.5.5.5 Interface oracle.jdbc.OracleResultSet

This interface extends standard JDBC result set functionality, implementing `get`*`XXX`* methods for retrieving data into `oracle.sql.*` objects.

4.5.5.6 Interface oracle.jdbc.OracleResultSetMetaData

This interface extends standard JDBC result set metadata functionality to retrieve information about Oracle result set objects.

> **See Also**
>
> "Using Result Set Metadata Extensions"

4.5.5.7 Class oracle.jdbc.OracleTypes

The `OracleTypes` class defines constants that JDBC uses to identify SQL types. Each variable in this class has a constant integer value. The `oracle.jdbc.OracleTypes` class duplicates the type code definitions of the standard Java `java.sql.Types` class and contains these additional type codes for Oracle extensions:

- `OracleTypes.BFILE`
- `OracleTypes.ROWID`
- `OracleTypes.CURSOR` (for `REF CURSOR` types)
- `OracleTypes.CHAR_BYTES` (for calling `setNull` and `setCHAR` methods on the same column)

As in `java.sql.Types`, all the variable names in `oracle.jdbc.OracleTypes` are also in uppercase text. JDBC uses the SQL types identified by the elements of the `OracleTypes` class in the following three main areas:

- Registering output parameters
- Using the `setNull` method
- Supporting the new `BOOLEAN` data type

Registering Output Parameters

The type codes in `java.sql.Types` or `oracle.jdbc.OracleTypes` identify the SQL types of the output parameters in the `registerOutParameter` method of the `java.sql.CallableStatement` and `oracle.jdbc.OracleCallableStatement` interfaces.

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These are the forms that the registerOutputParameter method can take for the CallableStatement and OracleCallableStatement interfaces

```
cs.registerOutParameter(int index, int sqlType);

cs.registerOutParameter(int index, int sqlType, String sql_name);

cs.registerOutParameter(int index, int sqlType, int scale);
```

In these signatures, index represents the parameter index, sqlType is the type code for the SQL data type, sql_name is the name given to the data type, for user-defined types, when sqlType is a STRUCT, REF, or ARRAY type code, and scale represents the number of digits to the right of the decimal point, when sqlType is a NUMERIC or DECIMAL type code.

The following example uses a CallableStatement interface to call a procedure named charout, which returns a CHAR data type. Note the use of the OracleTypes.CHAR type code in the registerOutParameter method.

```
CallableStatement cs = conn.prepareCall ("BEGIN charout (?); END;");
cs.registerOutParameter (1, OracleTypes.CHAR);
cs.execute ();
System.out.println ("Out argument is: " + cs.getString (1));
```

The next example uses a CallableStatement interface to call structout, which returns a STRUCT data type. The form of registerOutParameter requires you to specify the type code, Types.STRUCT or OracleTypes.STRUCT, as well as the SQL name, EMPLOYEE.

The example assumes that no type mapping has been declared for the EMPLOYEE type, so it is retrieved into a STRUCT data type. To retrieve the value of EMPLOYEE as an oracle.sql.STRUCT object, the statement object cs is cast to OracleCallableStatement and the Oracle extension getSTRUCT method is invoked.

```
CallableStatement cs = conn.prepareCall ("BEGIN structout (?); END;");
cs.registerOutParameter (1, OracleTypes.STRUCT, "EMPLOYEE");
cs.execute ();

// get the value into a STRUCT because it
// is assumed that no type map has been defined
STRUCT emp = ((OracleCallableStatement)cs).getSTRUCT (1);
```

Using the setNull Method

The type codes in Types and OracleTypes identify the SQL type of the data item, which the setNull method sets to NULL. The setNull method can be found in the java.sql.PreparedStatement and oracle.jdbc.OraclePreparedStatement interfaces.

These are the forms that the setNull method can take for the PreparedStatement and OraclePreparedStatement objects:

```
ps.setNull(int index, int sqlType);

ps.setNull(int index, int sqlType, String sql_name);
```

In these signatures, index represents the parameter index, sqlType is the type code for the SQL data type, and sql_name is the name given to the data type, for user-defined types, when sqlType is a STRUCT, REF, or ARRAY type code. If you enter an invalid sqlType, a ParameterTypeConflict exception is thrown.

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The following example uses a prepared statement to insert a null value into the database. Note the use of `OracleTypes.NUMERIC` to identify the numeric object set to `NULL`. Alternatively, `Types.NUMERIC` can be used.

```
PreparedStatement pstmt =
    conn.prepareStatement ("INSERT INTO num_table VALUES (?)");

pstmt.setNull (1, OracleTypes.NUMERIC);
pstmt.execute ();
```

In this example, the prepared statement inserts a `NULL STRUCT` object of type `EMPLOYEE` into the database.

```
PreparedStatement pstmt = conn.prepareStatement
                              ("INSERT INTO employees VALUES (?)");

pstmt.setNull (1, OracleTypes.STRUCT, "EMPLOYEE");
pstmt.execute ();
```

You can also use the `OracleTypes.CHAR_BYTES` type with the `setNull` method, if you also want to call the `setCHAR` method on the same column. For example:

```
 ps.setCHAR(n, aCHAR);
  ps.addBatch();
  ps.setNull(n, OracleTypes.CHAR_BYTES);
  ps.addBatch();
```

In this preceding example, any other type, apart from the `OracleTypes.CHAR_BYTES` type, will cause extra round trips to the Database. Alternatively, you can also write your code without using the `setNull` method. For example, you can also write your code as shown in the following example:

```
ps.setCHAR(n, null);
```

Supporting the BOOLEAN Data Type

Starting from Release 23ai, Oracle Database supports the `BOOLEAN` data type in compliance with the ISO SQL standard. The current release of JDBC Thin driver provides support for the newly introduced `BOOLEAN` data type, with the introduction of a new type `BOOLEAN` in `oracle.jdbc.OracleType`.

The following table lists the APIs to work with this new type:

Operation	API Used	Code Example

Insert	`java.sql.PreparedStatement.setBooleanorjava.sql.PreparedStatement.setObject`	**Example**:
		
		`...`
		`String query = "INSERT INTO BoolTable values (?) ";`
		`PreparedStatement pstmt = con.prepareStatement(query);`
		`pstmt.setBoolean(1, true);`
		`pstmt.execute();`
		`...`

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Operation	API Used	Code Example

Fetch	`java.sql.ResultSet.getBoolean` or any equivalent method	…
		`Statement stmt = con.createStatement();`
		`ResultSet rs = stmt.executeQuery("select * from BoolTable");`
		`while(rs.next()) {`
		`  System.out.print("Value: " + rs.getBoolean("booleanColumn"));`
		…
		`}`

Fetch column metadata	`java.sql.ResultSetMetaData`	`...`
		`try (OraclePreparedStatement stmt = (OraclePreparedStatement)`
		`  conn.prepareStatement("SELECT ? < ?")) {`
		`  ResultSetMetaData rsmd = stmt.getMetaData();`
		
		`System.out.print(rsmd.getColumnType(1) + " ");`
		
		`System.out.println(rsmd.getColumnTypeName(1) + " ");`
		`}`
		`...`
		
		The expected output of the preceding code snippet is: `16 BOOLEAN`

> **Note**
>
> If the columns with which the values are being compared to or the column into which values are inserted, are not of the appropriate types, then an implicit conversion may take place. If the value cannot be converted, an exception is thrown.

Supported and Unsupported Conversions for the BOOLEAN Type

Oracle Database allows implicit conversion from character and number types of data to `BOOLEAN` type, and `BOOLEAN` type to character and number types. So, you can also use external types for these types, while the Database takes care of implicit conversions for the binds and the client takes care of the implicit conversions for the defines.

The following table lists the supported conversions:

Java Type	Value	BOOLOEAN Value
boolean	TRUE or FALSE	TRUE or FALSE

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Java Type	Value	BOOLOEAN Value
String	"TRUE" or "FALSE" (case-insensitive)	TRUE or FALSE
`char`, `int`, `long`	Non-zero value or zero-value	TRUE or FALSE

The following table lists the String literals to represent "`True`" and "`False`":

True (case-insensitive)	False (case-insensitive)
"true"	"false"
"yes"	"no"
"on"	"off"
"1"	"0"
"t"	"f"
"y"	"n"

Conversion between the `NUMBER` and `BOOLEAN` types with non-zero scale returns an error. Also, when converting from string to `BOOLEAN`, if the string literal value is not any of the values listed in the preceding table, then an error is returned.

4.6 DML Returning

The DML returning feature provides more functionality compared to retrieval of auto-generated keys. It can be used to retrieve not only auto-generated keys, but also other columns or values that the application may use.

> **Note**
>
> - The server-side internal driver does not support DML returning and retrieval of auto-generated keys.
> - You cannot use both DML returning and retrieval of auto-generated keys in the same statement.

The following sections explain the support for DML returning:

- Oracle-Specific APIs
- About Running DML Returning Statements
- Example of DML Returning
- Limitations of DML Returning

4.6.1 Oracle-Specific APIs

The `OraclePreparedStatement` interface is enhanced with Oracle-specific application programming interfaces (APIs) to support DML returning. The `registerReturnParameter` and `getReturnResultSet` methods have been added to the

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oracle.jdbc.OraclePreparedStatement interface, to register parameters that are returned and data retrieved by DML returning.

The registerReturnParameter method is used to register the return parameter for DML returning. The method throws a SQLException instance if an error occurs. You must pass a positive integer specifying the index of the return parameter. You also must specify the type of the return parameter. You can also specify the maximum bytes or characters of the return parameter. This method can be used only with char or RAW types. You can also specify the fully qualified name of a SQL structure type.

> **Note**
>
> If you do not know the maximum size of the return parameters, then you should use registerReturnParameter(int paramIndex, int externalType), which picks the default maximum size. If you know the maximum size of return parameters, using registerReturnParameter(int paramIndex, int externalType, int maxSize) can reduce memory consumption.

The getReturnResultSet method fetches the data returned from DML returning and returns it as a ResultSet object. The method throws a SQLException exception if an error occurs.

4.6.2 About Running DML Returning Statements

Before running a DML returning statement, the JDBC application must call one or more of the registerReturnParameter methods. The method provides the JDBC drivers with information, such as type and size, of the return parameters. The DML returning statement is then processed using one of the standard JDBC APIs, executeUpdate or execute. You can then fetch the returned parameters as a ResultSet object using the getReturnResultSet method of the oracle.jdbc.OraclePreparedStatement interface.

In order to read the values in the ResultSet object, the underlying Statement object must be open. When the underlying Statement object is closed, the returned ResultSet object is also closed. This is consistent with ResultSet objects that are retrieved by processing SQL query statements.

When a DML returning statement is run, the concurrency of the ResultSet object returned by the getReturnResultSet method must be CONCUR_READ_ONLY and the type of the ResultSet object must be TYPE_FORWARD_ONLY or TYPE_SCROLL_INSENSITIVE.

4.6.3 Example of DML Returning

This section provides two code examples of DML returning.

The following code example illustrates the use of DML returning. In this example, assume that the maximum size of the name column is 100 characters. Because the maximum size of the name column is known, the registerReturnParameter(int paramIndex, int externalType, int maxSize) method is used.

```
...
OraclePreparedStatement pstmt = (OraclePreparedStatement)conn.prepareStatement(
       "delete from tab1 where age < ? returning name into ?");
pstmt.setInt(1,18);

/** register returned parameter
  * in this case the maximum size of name is 100 chars
```


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```
  */
pstmt.registerReturnParameter(2, OracleTypes.VARCHAR, 100);

// process the DML returning statement
count = pstmt.executeUpdate();
if (count>0)
{
  ResultSet rset = pstmt.getReturnResultSet(); //rest is not null and not empty
  while(rset.next())
  {
    String name = rset.getString(1);
    ...
  }
}
...
```

The following code example also illustrates the use of DML returning. However, in this case, the maximum size of the return parameters is not known. Therefore, the `registerReturnParameter(int paramIndex, int externalType)` method is used.

```
...
OraclePreparedStatement pstmt = (OraclePreparedStatement)conn.prepareStatement(
  "insert into lobtab values (100, empty_clob()) returning col1, col2 into ?, ?");

// register return parameters
pstmt.registerReturnParameter(1, OracleTypes.INTEGER);
pstmt.registerReturnParameter(2, OracleTypes.CLOB);

// process the DML returning SQL statement
pstmt.executeUpdate();
ResultSet rset = pstmt.getReturnResultSet();
int r;
CLOB clob;
if (rset.next())
{
  r = rset.getInt(1);
  System.out.println(r);
  clob = (CLOB)rset.getClob(2);
  ...
}
...
```

4.6.4 Limitations of DML Returning

When using DML returning, be aware of the following:

- It is unspecified what the `getReturnResultSet` method returns when it is invoked more than once. You should not rely on any specific action in this regard.
- The `ResultSet` objects returned from the execution of DML returning statements do not support the `ResultSetMetaData` type. Therefore, the applications must know the information of return parameters before running DML returning statements.
- Streams are not supported with DML returning.
- DML returning cannot be combined with batch update.
- You cannot use both the auto-generated key feature and the DML returning feature in a single SQL DML statement. For example, the following is not allowed:

  ```
  ...
  PreparedStatement pstmt = conn.prepareStatement('insert into orders (?, ?, ?)
  returning order_id into ?");
  ```


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```
pstmt.setInt(1, seq01.NEXTVAL);
pstmt.setInt(2, 100);
pstmt.setInt(3, 966431502);
pstmt.registerReturnParam(4, OracleTypes.INTEGER);
pstmt.executeUpdate;
ResultSet rset = pstmt.getGeneratedKeys;
...
```

4.7 Accessing PL/SQL Associative Arrays

Oracle JDBC drivers enable JDBC applications to make PL/SQL calls with Associative Arrays parameters. This section describes the methods to access Associative Arrays.

In PL/SQL, an Associative Array is a set of key-value pairs, where the keys may be `PLS_INTEGER`s or Strings. The keys may have any value and need not be dense. From a client application, you can work only with `PLS_INTEGER` or `BINARY_INTEGER` keys.

> **Note**
>
> - Associative Arrays were previously known as index-by tables.
> - The `PLS_INTEGER` and `BINARY_INTEGER` are identical data types.
> - When you use String data types, the size is limited to the size in PL/SQL that is 32767 characters. For the server-side internal driver, the limits are lower.

The previous release of Oracle JDBC drivers provided support only for PL/SQL Associative Arrays of Scalar data types. Also, the support was restricted only to the values of the key-value pairs of the Arrays. Starting from Release 18c, Oracle Database supports accessing both the keys (indexes) and values of Associative Arrays, and also provides support for Associative Arrays of object types. Use the following methods to achieve the new functionalities:

- ```
  Array createOracleArray(String arrayTypeName,
                          Object elements)
                          throws SQLException
  ```

- ```
  ARRAY createARRAY(String typeName,
                    Object elements)
                    throws SQLException
  ```


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> **Note**
>
> You can use the `createOracleArray` method and the `createARRAY` method for Associative Arrays on Oracle Database release 12*c* and later releases. If you are using an earlier release of Oracle Database, then you should continue using the following deprecated APIs:
>
> – `oracle.jdbc.OraclePreparedStatement.setPlsqlIndexTable`
> – `oracle.jdbc.OracleCallableStatement.getPlsqlIndexTable`
> – `oracle.jdbc.OracleCallableStatement.getOraclePlsqlIndexTable`
> – `oracle.jdbc.OracleCallableStatement.registerIndexTableOutParameter`

In both the preceding methods, the second parameter can either be a `java.util.Map<Integer, ?>` that holds the key-value pairs of the Associative Arrays, or it can only be an array of values. If it is an array of values, then the JDBC driver defaults the indexes to 0,1,2 and so on. If it is `java.util.Map<Integer, ?>`, then the JDBC driver does not default the keys. They remain as specified in the Map, and can be sparse and negative.

- `Map<?,?> oracle.jdbc.OracleArray.getJavaMap();`

  This method returns a `Map<?,?>` for the data types in the Associative Array and `null` for Nested Tables and VARRAYs.

> **See Also**
>
> - *Oracle AI Database JDBC Java API Reference*
> - *Oracle AI Database PL/SQL Language Reference* for more information about Associative Arrays

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5

Features Specific to JDBC Thin

This chapter introduces the Java Database Connectivity (JDBC) Thin client and covers the following features supported only by the JDBC Thin driver:

- Overview of JDBC Thin Client
- Additional Features Supported

5.1 Overview of JDBC Thin Client

The JDBC Thin client is a pure Java, Type IV driver. It is lightweight and easy to install. It provides high performance, comparable to the performance provided by the JDBC Oracle Call Interface (OCI) driver. The JDBC Thin driver is written entirely in Java, and therefore, it is platform-independent. Also, this driver does not require any additional Oracle software on the client-side.

The JDBC Thin driver communicates with the server using TTC, a protocol developed by Oracle to access data from Oracle Database. It can be used for application servers. The driver allows a direct connection to the database by providing an implementation of TCP/IP that implements Oracle Net and TTC on top of Java sockets. Both of these protocols are lightweight implementation versions of their counterparts on the server. The Oracle Net protocol runs over TCP/IP only.

The JDBC Thin driver can be used on both the client-side and the server-side. On the client-side, drivers can be used in Java applications that run either on the client or in the middle tier of a three-tier configuration. On the server-side, this driver is used to access a remote Oracle Database instance or another session on the same database.

5.2 Additional Features Supported

The JDBC Thin driver supports all standard JDBC features. The JDBC Thin driver also provides support for the following additional features:

- Default Support for Native XA
- Support for Transaction Guard
- Support for Application Continuity

5.2.1 Default Support for Native XA

Similar to the JDBC OCI driver, the JDBC Thin driver also provides support for Native XA. However, the JDBC Thin driver provides support for Native XA by default. This is unlike the case of the JDBC OCI driver, in which the support for Native XA is not enabled by default.

> **See Also**
>
> "Native-XA in Oracle JDBC Drivers"

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5.2.2 Support for Transaction Guard

Transaction Guard feature provides a generic infrastructure for at-most-once execution during planned and unplanned outages and duplicate submissions. Transaction Guard feature (along with Application Continuity feature) provides transparent session recovery and replay of SQL statements (queries and DMLs) since the beginning of the in-flight transaction.

> **See Also**
>
> Transaction Guard for Java

5.2.3 Support for Application Continuity

Application Continuity provides a general purpose, application-independent infrastructure that enables recovery of work from an application perspective, after the occurrence of a planned or unplanned outage. It provides the following benefits:

- Masking of outages from the end user
- Recovery of user environments, in-flight transactions, and lost outcome
- A single, easy, and foolproof method for applications to recover
- A definite target response time for applications, regardless of outages

> **See Also**
>
> Application Continuity for Java

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6

Features Specific to JDBC OCI Driver

This chapter introduces the features specific to the Java Database Connectivity (JDBC) Oracle Call Interface (OCI) driver. It also describes the OCI Instant Client. This chapter contains the following sections:

- OCI Connection Pooling
- Transparent Application Failover
- OCI Native XA
- OCI Instant Client
- About Instant Client Light (English)

6.1 OCI Connection Pooling

The OCI connection pooling feature is an Oracle-designed extension. The connection pooling provided by the JDBC OCI driver enables applications to have multiple logical connections, all of which are using a small set of physical connections. Each call on a logical connection is routed on to the physical connection that is available at the given time.

> **See Also**
>
> OCI Connection Pooling

6.2 Transparent Application Failover

The Transparent Application Failover feature of JDBC OCI driver enables you to automatically reconnect to a database if the database instance to which the connection is made goes down. The new database connection, though created by a different node, is identical to the original.

> **See Also**
>
> Transparent Application Failover

6.3 OCI Native XA

The JDBC OCI driver also provides a feature called Native XA. This feature enables to use native APIs to send XA commands. The native APIs provide high performance gains as compared to non-native APIs.

Related Topics

- OCI Native XA

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6.4 OCI Instant Client

The Instant Client facilitates the deployment OCI, Oracle C++ Call Interface (OCCI), Open Database Connectivity (ODBC), and JDBC-OCI based customer applications, by eliminating the need for an Oracle home.

The storage space requirement of a JDBC OCI application, using the Instant Client, is significantly reduced compared to the same application running on a full client-side installation as the Instant Client shared libraries occupy only about one-fourth of the disk space used by a full client installation.

See Also

Installing Oracle Instant Client

6.5 About Instant Client Light (English)

The lightweight version of the Instant Client is called Instant Client Light (English). It is a significantly smaller version of the Instant Client, which reduces the disk space requirements of the client installation by about 63 MB.

See Also

Installing Oracle Instant Client Basic Light

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7

Server-Side Internal Driver

This chapter covers the following topics:

- Overview of the Server-Side Internal Driver
- Connecting to the Database
- About Session and Transaction Context
- Testing JDBC on the Server
- Loading an Application into the Server

7.1 Overview of the Server-Side Internal Driver

The server-side internal driver is intrinsically tied to Oracle Database and to the embedded Java Virtual Machine, also known as Oracle Java Virtual Machine (Oracle JVM). The driver runs as part of the same process as the Database. It also runs within the default session, the same session in which the Oracle JVM was started. Each Oracle JVM session has a single implicit native connection to the Database session in which it exists. This connection is conceptual and is not a Java object. It is an inherent aspect of the session and cannot be opened or closed from within the JVM.

The server-side internal driver is optimized to run within the database server and provide direct access to SQL data and PL/SQL subprograms on the local database. The entire JVM operates in the same address space as the database and the SQL engine. Access to the SQL engine is a function call. This enhances the performance of your Java Database Connectivity (JDBC) applications and is much faster than running a remote Oracle Net call to access the SQL engine.

The server-side internal driver supports the same features, application programming interfaces (APIs), and Oracle extensions as the client-side drivers. This makes application partitioning very straightforward. For example, if you have a Java application that is data-intensive, then you can easily move it into the database server for better performance, without having to modify the application-specific calls.

7.2 Connecting to the Database

As described in the preceding section, the server-side internal driver runs within a default session. Therefore, you are already connected. There are two methods to access the default connection:

- Use the `OracleDataSource.getConnection` method, with any of the following forms as the URL string:
  - `jdbc:oracle:kprb`
  - `jdbc:default:connection`
  - `jdbc:oracle:kprb:`
  - `jdbc:default:connection:`
- Use the Oracle-specific `defaultConnection` method of the `OracleDriver` class.

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Using `defaultConnection` is generally recommended.

> **Note**
>
> You are no longer required to register the `OracleDriver` class for connecting with the server-side internal driver.

Connecting with the OracleDriver Class defaultConnection Method

The `defaultConnection` method of the `oracle.jdbc.OracleDriver` class is an Oracle extension and always returns the same connection object. Even if you call this method multiple times, assigning the resulting connection object to different variable names, then only a single connection object is reused.

You need *not* include a connection string in the `defaultConnection` call. For example:

```
import java.sql.*;
import oracle.jdbc.*;

class JDBCConnection
{
  public static Connection connect() throws SQLException
  {
    Connection conn = null;
    try {
      // connect with the server-side internal driver

         conn = ora.defaultConnection();
      }

    } catch (SQLException e) {...}
    return conn;
  }
}
```

Note that there is no `conn.close` call in the example. When JDBC code is running inside the target server, the connection is an implicit data channel, not an explicit connection instance as from a client. It should *not* be closed.

OracleDriver has a static variable to store a default connection instance. The method `OracleDriver.defaultConnection` returns this default connection instance if the connection exists and is not closed. Otherwise, it creates a new, open instance and stores it in the static variable and returns it to the caller.

Typically, you should use the `OracleDriver.defaultConnection` method. This method is faster and uses less resources. Java stored procedures should be carefully written. For example, to close statements before the end of each call.

Typically, you should not close the default connection instance because it is a single instance that can be stored in multiple places, and if you close the instance, each would become unusable. If it is closed, a later call to the `OracleDriver.defaultConnection` method gets a new, open instance.

Connecting with the OracleDataSource.getConnection Method

To connect to the internal server connection from code that is running within the target server, you can use the `OracleDataSource.getConnection` method with either of the following URLs:

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```
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:oracle:kprb");
Connection conn = ods.getConnection();
```

or:

```
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:default:connection");
Connection conn = ods.getConnection();
```

Any user name or password you include in the URL is ignored in connecting to the default server connection.

The `OracleDataSource.getConnection` method returns a new Java `Connection` object every time you call it. The fact that `OracleDataSource.getConnection` returns a new connection object every time you call it is significant if you are working with object maps or type maps. A type map is associated with a specific `Connection` object and with any state that is part of the object. If you want to use multiple type maps as part of your program, then you can call `getConnection` to create a new `Connection` object for each type map.

> **Note**
>
> Although the `OracleDataSource.getConnection` method returns a new object every time you call it, it does not create a new database connection every time. They all utilize the same implicit native connection and share the same session state, in particular, the local transaction.

7.3 About Session and Transaction Context

The server-side driver operates within a default session and default transaction context. The default session is the session in which the JVM was started. In effect, you are already connected to the database on the server. This is different from the client-side where there is no default session. You must explicitly connect to the database.

Auto-commit mode is disabled in the server. You must manage transaction `COMMIT` and `ROLLBACK` operations explicitly by using the appropriate methods on the connection object:

```
conn.commit();
```

or:

```
conn.rollback();
```

> **Note**
>
> As a best practice, it is recommended not to commit or rollback a transaction inside the server.

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7.4 Testing JDBC on the Server

Almost any JDBC program that can run on a client can also run on the server. All the programs in the `samples` directory can be run on the server, with only minor modifications. Usually, these modifications concern only the connection statement.

Consider the following code fragment which obtains a connection to a database:

```
ods.setUrl(
"jdbc:oracle:oci:@(DESCRIPTION=
  (ADDRESS=(PROTOCOL=TCP)(HOST=cluster_alias)
    (PORT=5221))
    (CONNECT_DATA=(SERVICE_NAME=orcl)))");
ods.setUser("HR");
ods.setPassword("hr");
Connection conn = ods.getConnection();
```

We can modify this code fragment for use in the server-side internal driver. In the server-side internal driver, no user, password, or database information is necessary. For the connection statement, you use:

```
ods.setUrl(
"jdbc:oracle:kprb:@");
Connection conn = ods.getConnection();
```

However, the most convenient way to get a connection is to call the `OracleDriver.defaultConnection` method, as follows:

```
Connection conn = OracleDriver.defaultConnection();
```

7.5 Loading an Application into the Server

When loading an application into the server, you can load `.class` files that you have already compiled on the client or you can load `.java` source files and have them automatically compiled on the server.

7.5.1 Using the Loadjava Utility

You can use the `loadjava` utility to load your files. You can either specify source file names on the command line or put the files into a Java Archive (JAR) file and specify the JAR file name on the command line.

The `loadjava` script, which runs the actual utility, is in the `bin` directory in your Oracle home. This directory should already be in your path once Oracle has been installed.

> **Note**
>
> The `loadjava` utility supports compressed files.

Loading Class Files into the Server

Consider a case where you have the following three class files in your application: `Foo1.class`, `Foo2.class`, and `Foo3.class`. Each class is written into its own class schema object in the server.

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You can load the class files using the default JDBC Oracle Call Interface (OCI) driver in the following ways:

- Specifying the individual class file names, as follows:

```
loadjava -user HR Foo1.class Foo2.class Foo3.class
Password: password
```

- Specifying the class file names using a wildcard, as follows:

```
loadjava -user HR Foo*.class
Password: password
```

- Specifying a JAR file that contains the class files, as follows:

```
loadjava -user HR Foo.jar
Password: password
```

You can load the files using the JDBC Thin driver, as follows:

```
loadjava -thin -user HR@localhost:5221:orcl Foo.jar
Password: password
```

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), JDK 6, and JDK 7 are supported. However, only one of the JVMs will be active at a given time.
>
> Ensure that your classes are not compiled using a newer version of JDK than the active runtime version on the server.

Loading Source Files into the Server

If you enable the `loadjava -resolve` option when loading a `.java` source file, then the server-side compiler will compile your application as it is loaded, resulting in both a source schema object for the original source code and one or more class schema objects for the compiled output.

If you do not specify `-resolve`, then the source is loaded into a source schema object without any compilation. In this case, however, the source is implicitly compiled the first time an attempt is made to use a class defined in the source.

For example, run `loadjava` as follows to load and compile `Foo.java`, using the default JDBC OCI driver:

```
loadjava -user HR -resolve Foo.java
Password: password
```

Or, use the following command to load using the JDBC Thin driver:

```
loadjava -thin -user HR@localhost:5221:orcl -resolve Foo.java
Password: password
```

Either of these will result in appropriate class schema objects being created in addition to the source schema object.

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> **Note**
>
> Oracle generally recommends compiling source on the client, whenever possible, and loading the `.class` files instead of the source files into the server.

> **See Also**
>
> *Oracle Database Java Developer's Guide*

7.5.2 Using the JVM Command Line

You can also use the JVM command-line option to load your files. The command-line interface to Oracle JVM is analogous to using the JDK or JRE shell commands. You can:

- Use the standard `-classpath` syntax to indicate where to find the classes to load
- Set the system properties by using the standard `-D` syntax

The interface is a PL/SQL function that takes a string (`VARCHAR2`) argument, parses it as a command-line input and if it is properly formed, runs the indicated Java method in Oracle JVM. To do this, PL/SQL package `DBMS_JAVA` provides the following functions:

- `runjava`

  You can use the `runjava` function in the following way:

  ```
  FUNCTION runjava(cmdline VARCHAR2) RETURN VARCHAR2;
  ```

- `runjava_in_current_session`

  You can use the `runjava_in_current_session` function in the following way:

  ```
  FUNCTION runjava_in_current_session(cmdline VARCHAR2) RETURN VARCHAR2;
  ```

> **Note**
>
> Starting with Oracle Database 11*g* Release 1, there is a just-in-time (JIT) compiler for Oracle JVM environment. A JIT compiler for Oracle JVM enables much faster execution because the JIT compiler uses advanced techniques as compared to the old Native compiler and compiles dynamically generated code. Unlike the old Native compiler, the JIT compiler does not require a C compiler. It is enabled without the support of any plug-ins.

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Part III
Connection and Security

This part consists of chapters that discuss the use of data sources and URLs to connect to the database. It also includes chapters that discuss the security features supported by the Oracle Java Database Connectivity (JDBC) Oracle Call Interface (OCI) and Thin drivers, TLS (Transport Layer Security) support in JDBC Thin driver, and middle-tier authentication through proxy connections.

Part III contains the following chapters:

- Data Sources and URLs
- JDBC Client-Side Security Features
- JDBC Service Provider Extensions
- Proxy Authentication

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8

Data Sources and URLs

This chapter discusses connecting applications to databases using Java Database Connectivity (JDBC) data sources, as well as the URLs that describe databases. This chapter contains the following sections:

- About Data Sources
- Database URLs and Database Specifiers

8.1 About Data Sources

Data sources are standard, general-use objects for specifying databases or other resources to use. The JDBC 2.0 extension application programming interface (API) introduced the concept of data sources. For convenience and portability, data sources can be bound to Java Naming and Directory Interface (JNDI) entities, so that you can access databases by logical names.

The data source facility provides a complete replacement for the previous JDBC `DriverManager` facility. You can use both facilities in the same application, but it is recommended that you transition your application to data sources.

This section covers the following topics:

- Overview of Oracle Data Source Support for JNDI
- Features and Properties of Data Sources
- Creating a Data Source Instance and Connecting
- Creating a Data Source Instance_ Registering with JNDI_ and Connecting
- Supported Connection Properties
- About Using Roles for SYS Login
- Configuring Database Remote Login
- Using Bequeath Connection and SYS Logon
- Setting Properties for Oracle Performance Extensions
- Support for Network Data Compression

8.1.1 Overview of Oracle Data Source Support for JNDI

The JNDI standard provides a way for applications to find and access remote services and resources. These services can be any enterprise services. However, for a JDBC application, these services would include database connections and services.

JNDI enables an application to use logical names in accessing these services, removing vendor-specific syntax from application code. JNDI has the functionality to associate a logical name with a particular source for a desired service.

All Oracle JDBC data sources are JNDI-referenceable. The developer is not required to use this functionality, but accessing databases through JNDI logical names makes the code more portable.

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> **Note**
>
> Using JNDI functionality requires the `jndi.jar` file to be in the `CLASSPATH` environment variable. This file is included with the Java products on the installation CD. You must add it to the `CLASSPATH` environment variable separately.

8.1.2 Features and Properties of Data Sources

By using the data source functionality with JNDI, you do not need to register the vendor-specific JDBC driver class name and you can use logical names for URLs and other properties. This ensures that the code for opening database connections is portable to other environments.

The DataSource Interface and Oracle Implementation

A JDBC data source is an instance of a class that implements the standard `javax.sql.DataSource` interface:

```
public interface DataSource
{
   Connection getConnection() throws SQLException;
   Connection getConnection(String username, String password)
      throws SQLException;
   ...
}
```

Oracle implements this interface with the `OracleDataSource` class in the `oracle.jdbc.pool` package. The overloaded `getConnection` method returns a connection to the database.

To use other values, you can set properties using appropriate setter methods. For alternative user names and passwords, you can also use the `getConnection` method that takes these parameters as input. This would take priority over the property settings.

> **Note**
>
> The `OracleDataSource` class and all subclasses implement the `java.io.Serializable` and `javax.naming.Referenceable` interfaces.

Properties of DataSource

The `OracleDataSource` class, as with any class that implements the `DataSource` interface, provides a set of properties that can be used to specify a database to connect to. These properties follow the JavaBeans design pattern.

The following tables list the `OracleDataSource` standard properties and Oracle extensions respectively.

> **Note**
>
> Oracle does not implement the standard `roleName` property.

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Table 8-1 Standard Data Source Properties

Name	Type	Description
`databaseName`	`String`	Name of the particular database on the server.
`dataSourceName`	`String`	Name of the underlying data source class. For connection pooling, this is an underlying pooled connection data source class. For distributed transactions, this is an underlying XA data source class.
`description`	`String`	Description of the data source.
`networkProtocol`	`String`	Network protocol for communicating with the server. For Oracle, this applies only to the JDBC Oracle Call Interface (OCI) drivers and defaults to `tcp`.
`password`	`String`	Password for the connecting user.
`portNumber`	`int`	Number of the port where the server listens for requests
`serverName`	`String`	Name of the database server
`user`	`String`	User name to log in

> **Note**
>
> For security reasons, there is no `getPassword()` method.

Table 8-2 Oracle Extended Data Source Properties

Name	Type	Description
`connectionCacheName`	`String`	Specifies the name of the cache. This cannot be changed after the cache has been created.
`connectionCacheProperties`	`java.util.Properties`	Specifies properties for implicit connection cache.
`connectionCachingEnabled`	`Boolean`	Specifies whether implicit connection cache is in use.
`connectionProperties`	`java.util.Properties`	Specifies the connection properties.
`driverType`	`String`	Specifies Oracle JDBC driver type. It can be one of `oci`, `thin`, or `kprb`.
`fastConnectionFailoverEnabled`	`Boolean`	Specifies whether Fast Connection Failover is in use.
`implicitCachingEnabled`	`Boolean`	Specifies whether the implicit statement connection cache is enabled.
`loginTimeout`	`int`	Specifies the maximum time in seconds that this data source will wait while attempting to connect to a database.
`logWriter`	`java.io.PrintWriter`	Specifies the log writer for this data source.
`maxStatements`	`int`	Specifies the maximum number of statements in the application cache.

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Table 8-2 (Cont.) Oracle Extended Data Source Properties

Name	Type	Description
`serviceName`	`String`	Specifies the database service name for this data source.
`tnsEntry`	`String`	Specifies the TNS entry name. The TNS entry name corresponds to the TNS entry specified in the `tnsnames.ora` configuration file. Enable this `OracleXADataSource` property when using the Native XA feature with the OCI driver, to access Oracle pre-8.1.6 databases and later. If the `tnsEntry` property is not set when using the Native XA feature, then a `SQLException` with error code ORA-17207 is thrown
`url`	`String`	Specifies the URL of the database connection string. Provided as a convenience, it can help you migrate from an older Oracle Database. You can use this property in place of the Oracle `tnsEntry` and `driverType` properties and the standard `portNumber`, `networkProtocol`, `serverName`, and `databaseName` properties.
`nativeXA`	`Boolean`	Allows an `OracleXADataSource` using the Native XA feature with the OCI driver, to access Oracle pre-8.1.6 databases and later. If the `nativeXA` property is enabled, be sure to set the `tnsEntry` property as well. This property is only for `OracleXADatasource`. This `DataSource` property defaults to `false`.
`ONSConfiguration`	`String`	Specifies the ONS configuration string that is used to remotely subscribe to FAN/ONS events.

Note

- This table omits properties that supported the deprecated connection cache based on `OracleConnectionCache`.
- Because Native XA performs better than Java XA, use Native XA whenever possible.

Use the `setConnectionProperties` method to set the properties of the connection and the `setConnectionCacheProperties` method to set the properties of the connection cache.

If you are using the server-side internal driver, that is, the `driverType` property is set to `kprb`, then any other property settings are ignored.

If you are using the JDBC Thin or OCI driver, then note the following:

- A URL setting can include settings for `user` and `password`, as in the following example, in which case this takes precedence over individual `user` and `password` property settings:

  ```
  jdbc:oracle:thin:HR/<password>@localhost:5221:orcl
  ```


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- Settings for `user` and `password` are required, either directly through the URL setting or through the `getConnection` call. The `user` and `password` settings in a `getConnection` call take precedence over any property settings.
- If the `url` property is set, then any `tnsEntry`, `driverType`, `portNumber`, `networkProtocol`, `serverName`, and `databaseName` property settings are ignored.
- If the `tnsEntry` property is set, which presumes the `url` property is not set, then any `databaseName`, `serverName`, `portNumber`, and `networkProtocol` settings are ignored.
- If you are using an OCI driver, which presumes the `driverType` property is set to `oci`, and the `networkProtocol` is set to `ipc`, then any other property settings are ignored.

Also, note that `getConnectionCacheName()` will return the name of the cache only if the `ConnectionCacheName` property of the data source is set after caching is enabled on the data source.

8.1.3 Creating a Data Source Instance and Connecting

This section shows an example of the most basic use of a data source to connect to a database, without using JNDI functionality. Note that this requires vendor-specific, hard-coded property settings.

Create an `OracleDataSource` instance, initialize its connection properties as appropriate, and get a connection instance, as in the following example:

```
OracleDataSource ods = new OracleDataSource();
ods.setDriverType("oci");
ods.setServerName("localhost");
ods.setNetworkProtocol("tcp");
ods.setDatabaseName(<database_name>);
ods.setPortNumber(5221);
ods.setUser("HR");
ods.setPassword("hr");
Connection conn = ods.getConnection();
```

Or, optionally, override the user name and password, as follows:

```
Connection conn = ods.getConnection("OE", "oe");
```

8.1.4 Creating a Data Source Instance, Registering with JNDI, and Connecting

This section exhibits JNDI functionality in using data sources to connect to a database. Vendor-specific, hard-coded property settings are required only in the portion of code that binds a data source instance to a JNDI logical name. From that point onward, you can create portable code by using the logical name in creating data sources from which you will get your connection instances.

> **Note**
>
> Creating and registering data sources is typically handled by a JNDI administrator, not in a JDBC application.

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Initialize Data Source Properties

Create an `OracleDataSource` instance, and then initialize its properties as appropriate, as in the following example:

```
OracleDataSource ods = new OracleDataSource();
ods.setDriverType("oci");
ods.setServerName("localhost");
ods.setNetworkProtocol("tcp");
ods.setDatabaseName("816");
ods.setPortNumber(5221);
ods.setUser("HR");
ods.setPassword("hr");
```

Register the Data Source

Once you have initialized the connection properties of the `OracleDataSource` instance `ods`, as shown in the preceding example, you can register this data source instance with JNDI, as in the following example:

```
Context ctx = new InitialContext();
ctx.bind("jdbc/sampledb", ods);
```

Calling the JNDI `InitialContext()` constructor creates a Java object that references the initial JNDI naming context. System properties, which are not shown, instruct JNDI which service provider to use.

The `ctx.bind` call binds the `OracleDataSource` instance to a logical JNDI name. This means that anytime after the `ctx.bind` call, you can use the logical name `jdbc/sampledb` in opening a connection to the database described by the properties of the `OracleDataSource` instance `ods`. The logical name `jdbc/sampledb` is logically bound to this database.

The JNDI namespace has a hierarchy similar to that of a file system. In this example, the JNDI name specifies the subcontext `jdbc` under the root naming context and specifies the logical name `sampledb` within the `jdbc` subcontext.

The `Context` interface and `InitialContext` class are in the standard `javax.naming` package.

> **Note**
>
> The JDBC 2.0 Specification requires that all JDBC data sources be registered in the `jdbc` naming subcontext of a JNDI namespace or in a child subcontext of the `jdbc` subcontext.

Open a Connection

To perform a lookup and open a connection to the database logically bound to the JNDI name, use the logical JNDI name. Doing this requires casting the lookup result, which is otherwise a Java `Object`, to `OracleDataSource` and then using its `getConnection` method to open the connection.

Here is an example:

```
OracleDataSource odsconn = (OracleDataSource)ctx.lookup("jdbc/sampledb");
Connection conn = odsconn.getConnection();
```


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8.1.5 Supported Connection Properties

For a detailed list of connection properties that Oracle JDBC drivers support, see the *Oracle Database JDBC Java API Reference*.

> **Note**
>
> The JDBC Thin Driver connection property `oracle.jdbc.ReadTimeout` and the JDBC method `java.sql.Connection.setNetworkTimeout` may not behave as expected, when Dead Connection Detection (DCD) is enabled in the old way in Oracle Database. See the following My Oracle Support Note for more information about the new implementation of DCD: https://support.oracle.com/rs?type=doc&id=1591874.1

8.1.6 About Using Roles for SYS Login

To specify the role for the `SYS` login, use the `internal_logon` connection property. To log on as `SYS`, set the `internal_logon` connection property to `SYSDBA` or `SYSOPER`.

> **Note**
>
> The ability to specify a role is supported only for the `sys` user name.

For a bequeath connection, we can get a connection as `SYS` by setting the `internal_logon` property. For a remote connection, we need additional password file setting procedures.

8.1.7 Configuring Database Remote Login

Before the JDBC Thin driver can connect to the database as `SYSDBA`, you must configure the user, because Oracle Database security system requires a password file for remote connections as an administrator. Perform the following:

1. Set a password file on the server-side or on the remote database, using the `orapwd` password utility. You can add a password file for user `SYS` as follows:
   - In UNIX

     ```
     orapwd file=$ORACLE_HOME/dbs/orapwORACLE_SID entries=200
     Enter password: password
     ```

   - In Microsoft Windows

     ```
     orapwd file=%ORACLE_HOME%\database\PWDORACLE_SID.ora entries=200
     Enter password: password
     ```

   In this case, `file` is the name of the password file, *`password`* is the password for user `SYS`. It can be altered using the `ALTER USER` statement in SQL Plus. You should set `entries` to a value higher than the number of entries you expect.

   The syntax for the password file name is different on Microsoft Windows and UNIX.

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> **See Also**
>
> *Oracle AI Database Administrator's Guide*

2. Enable remote login as SYSDBA. This step grants SYSDBA and SYSOPER system privileges to individual users and lets them connect as themselves.

   Stop the database, and add the following line to init*service_name*.ora, in UNIX, or init.ora, in Microsoft Windows:

   ```
   remote_login_passwordfile=exclusive
   ```

   The init*service_name*.ora file is located at *ORACLE_HOME*/dbs/ and also at *ORACLE_HOME*/admin/db_name/pfile/. Ensure that you keep the two files synchronized.

   The init.ora file is located at %ORACLE_BASE%\ADMIN\db_name\pfile\.

3. Change the password for the SYS user. This is an optional step.

   ```
   PASSWORD sys
          Changing password for sys
   New password: password
   Retype new password: password
   ```

4. Verify whether SYS has the SYSDBA privilege.

   ```
   SQL> select * from v$pwfile_users;
   USERNAME                       SYSDB        SYSOP
   ----------------------         ---------    ---------
   SYS                            TRUE         TRUE
   ```

5. Restart the remote database.

Example 8-1 Using SYS Login To Make a Remote Connection

```
//This example works regardless of language settings of the database.
 /** case of remote connection using sys **/
import java.sql.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.*;
// create an OracleDataSource
OracleDataSource ods = new OracleDataSource();
// set connection properties
java.util.Properties prop = new java.util.Properties();
prop.put("user", "sys");
prop.put("password", "sys");
prop.put("internal_logon", "sysoper");
ods.setConnectionProperties(prop);
// set the url
// the url can use oci driver as well as:
// url = "jdbc:oracle:oci8:@remotehost"; the remotehost is a remote database
String url = "jdbc:oracle:thin:@localhost:5221/orcl";
ods.setURL(url);
// get the connection
Connection conn = ods.getConnection();
...
```

8.1.8 Using Bequeath Connection and SYS Logon

The following example illustrates how to use the internal_logon and SYSDBA arguments to specify the SYS login. This example works regardless of the database's national-language settings of the database.

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```
/** Example of bequeath connection **/
import java.sql.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.*;

// create an OracleDataSource instance
OracleDataSource ods = new OracleDataSource();

// set neccessary properties
java.util.Properties prop = new java.util.Properties();
prop.put("user", "sys");
prop.put("password", "sys");
prop.put("internal_logon", "sysdba");
ods.setConnectionProperties(prop);

// the url for bequeath connection
String url = "jdbc:oracle:oci8:@";
ods.setURL(url);

// retrieve the connection
Connection conn = ods.getConnection();
...
```

8.1.9 Setting Properties for Oracle Performance Extensions

Some of the connection properties are for use with Oracle performance extensions. Setting these properties is equivalent to using corresponding methods on the `OracleConnection` object, as follows:

- Setting the `defaultRowPrefetch` property is equivalent to calling `setDefaultRowPrefetch`.
- Setting the `remarksReporting` property is equivalent to calling `setRemarksReporting`.

> **See Also**
>
> "About Reporting DatabaseMetaData TABLE_REMARKS"

Example

The following example shows how to use the `put` method of the `java.util.Properties` class, in this case, to set Oracle performance extension parameters.

```
//import packages and register the driver
import java.sql.*;
import java.math.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.OracleDataSource;

//specify the properties object
java.util.Properties info = new java.util.Properties();
info.put ("user", "HR");
info.put ("password", "hr");
info.put ("defaultRowPrefetch","20");
info.put ("defaultBatchValue", "5");

//specify the datasource object
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:oracle:thin:@localhost:5221/orcl");
ods.setUser("HR");
```


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```
ods.setPassword("hr");
ods.setConnectionProperties(info);
...
```

8.1.10 Support for Network Data Compression

Starting from Oracle Database 12*c* Release 2 (12.2.0.1), the JDBC Thin driver supports network data compression. Network data compression reduces the size of the session data unit (SDU) transmitted over a data connection and reduces the time required to transmit a SQL query and the result across the network. The benefits are more significant in case of Wireless Area Network (WAN). For enabling network data compression, you must set the connection properties in the following way:

> **Note**
>
> Network compression does not work for streamed data.

```
...
OracleDataSource ds = new OracleDataSource();
Properties prop = new Properties();
prop.setProperty("user","user1");
prop.setProperty("password",<password>);

// Enabling Network Compression
prop.setProperty("oracle.net.networkCompression","on");

//Optional configuration for setting the client compression threshold.
prop.setProperty("oracle.net.networkCompressionThreshold","1024");

ds.setConnectionProperties(prop);
ds.setURL(url);
Connection conn = ds.getConnection();
...
```

8.2 Database URLs and Database Specifiers

Database URLs are strings. The complete URL syntax is:

`jdbc:oracle:`*`driver_type`*`:[`*`username/password`*`]@`*`database_specifier`*

> **Note**
>
> - The brackets indicate that the *`username/password`* pair is optional.
> - `kprb`, the internal server-side driver, uses an implicit connection. Database URLs for the server-side driver end after the *`driver_type`*.

The first part of the URL specifies which JDBC driver is to be used. The supported *`driver_type`* values are `thin`, `oci`, and `kprb`.

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The remainder of the URL contains an optional user name and password separated by a slash, an @, and the database specifier, which uniquely identifies the database to which the application is connected. Some database specifiers are valid only for the JDBC Thin driver, some only for the JDBC OCI driver, and some for both.

8.2.1 Support for Longer Passwords

In previous releases, the Oracle Database password length was up to 30 bytes. Starting with Oracle Database Release 23ai, Oracle Database supports passwords up to 1024 bytes in length.

The increased maximum password length provides the following benefits:

- It accommodates passwords that are used by Oracle Identity Cloud Service (IDCS) and Identity Access Management (IAM). The increase to 1024 bytes enables uniform password rules for all Cloud deployments.
- The 30-byte limitation was too restrictive when password multibyte characters used more than 1 byte in an NLS configuration.

8.2.2 Support for Internet Protocol Version 6

This release of Oracle JDBC drivers supports Internet Protocol Version 6 (IPv6) addresses in the JDBC URL and machine names that resolve to IPv6 addresses. IPv6 is a new Network layer protocol designed by the Internet Engineering Task Force (IETF) to replace the current version of Internet Protocol, Internet Protocol Version 4 (IPv4). The primary benefit of IPv6 is a large address space, derived from the use of 128-bit addresses. IPv6 also improves upon IPv4 in areas such as routing, network auto configuration, security, quality of service, and so on.

> **Note**
>
> - An IPv6 Client can support only IPv6 Servers or servers with dual protocol support, that is, support for both IPv6 and IPv4 protocols. Conversely, an IPv6 Server can support only IPv6 clients or dual protocol clients.
> - IPv6 is supported only with single instance Database servers and not with Oracle RAC.

If you want to use a literal IPv6 address in a URL, then you should enclose the literal address enclosed in a left bracket ([) and a right bracket (]). For example: `[2001:0db8:7654:3210:FEDC:BA98:7654:3210]`. So, a JDBC URL, using an IPv6 address will look like the following:

```
jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
  (HOST=[2001:0db8:7654:3210:FEDC:BA98:7654:3210])(PORT=5521))
  (CONNECT_DATA=(SERVICE_NAME=sales.example.com))
```


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> **Note**
>
> All the new System classes that are required for IPv6 support are loaded when Java is enabled during database initialization. So, if your application does not have any IPv6 addressing, then you do not need to change your code to use IPv6 functionality. However, if your application has either IPv6 only or both IPv6 and IPv4 addressing, then you should set the `java.net.preferIPv6Addresses` system property in the command line. This enables the Oracle JVM to load appropriate libraries. These libraries are loaded once and cannot be reloaded without restarting the Java process.

8.2.3 Support for HTTPS Proxy Configuration

Oracle Database Release 18c JDBC drivers support HTTPS Proxy Configuration. HTTPS Proxy enables tunnelling secure connections over forward HTTP proxy using the `HTTP CONNECT` method. This helps in accessing the public cloud database service as it eliminates the requirement to open an outbound port on a client side firewall. This parameter is applicable only to the connect descriptors where `PROTOCOL=TCPS`. This is similar to the web browser setting for intranet users who want to connect to internet hosts.

For configuring HTTPS Proxy, add details to the `ADDRESS` part of the Connection String as shown in the following code snippet:

```
(DESCRIPTION=

  (ADDRESS=(HTTPS_PROXY=sales-proxy)(HTTPS_PROXY_PORT=8080)(PROTOCOL=TCPS)
(HOST=sales2-svr)(PORT=443))

  (CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))
```

8.2.4 Database Specifiers

Table 8-3, shows the possible database specifiers, listing which JDBC drivers support each specifier.

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Table 8-3 Supported Database Specifiers

Specifier	Supported Drivers	Example

Oracle Net connect descriptor	Thin, OCI	Thin, using an address list:
		
		`jdbc:oracle:thin:@(DESCRIPTION=`
		`  (LOAD_BALANCE=on)`
		`(ADDRESS_LIST=`
		`  (ADDRESS=(PROTOCOL=TCP)(HOST=host1) (PORT=5221))`
		` (ADDRESS=(PROTOCOL=TCP)(HOST=host2)(PORT=5221)))`
		` (CONNECT_DATA=(SERVICE_NAME=orcl)))`
		
		OCI, using a cluster:
		
		`jdbc:oracle:oci:@(DESCRIPTION=`
		`  (ADDRESS=(PROTOCOL=TCP)(HOST=cluster_alias)`
		`  (PORT=5221))`
		`  (CONNECT_DATA=(SERVICE_NAME=orcl)))`

Thin-style service name	Thin	This is deprecated in favor of the Easy Connect Plus syntax. Refer to "Support for Easy Connect Plus" for more details. `jdbc:oracle:thin:HR/<password>@localhost:5221/orcl`

LDAP syntax	Thin	This is deprecated in favor of the Easy Connect Plus syntax. Refer to "Support for Easy Connect Plus" for more details.
		
		`jdbc:oracle:thin:@ldap:ldap.example.com:7777/`
		`sales,cn=OracleContext,dc=com`

Easy Connect Plus syntax	Thin	This format can be used to connect using the following:
		• The TLS protocol:
		`jdbc:oracle:thin:@tcps://salesserver1:1521/`
		`sales.us.example.com?wallet_location=/work/`
		`wallet/`
		• Plain TCP:
		`jdbc:oracle:thin:@//salesserver1:1521/`
		`sales.us.example.com`
		• Net connect descriptor stored in an LDAP directory:
		`jdbc:oracle:thin:@ldaps://myldapserver:1636/`
		`cn=orcl,cn=OracleContext,dc=example,dc=com`
		
		Refer to the "oracle.jdbc.OracleDriver class for more details

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Table 8-3 (Cont.) Supported Database Specifiers

Specifier	Supported Drivers	Example

Bequeath connection	Thin, OCI	For the Thin driver:
		`jdbc:oracle:thin:@(DESCRIPTION=(LOCAL=YES)(ADDRESS=(PROTOCOL=beq))(ENVS=ORACLE_HOME=/var/lib/oracle/dbhome,ORACLE_SID=oraclesid))`
		Refer to "Support for the Bequeath Protocol" for more details.
		For the OCI driver, it is empty, that is, nothing is specified after @
		`jdbc:oracle:oci:HR/<password>/@`

TNSNames alias	Thin, OCI	Refer to "TNSNames Alias Syntax" for details.
		`jdbc:oracle:thin:@<alias-name>?TNS_ADMIN=/work/tnsadmin/`
		You can also configure the TNSNames alias through an API:
		`OracleDataSource ods = new OracleDataSource();`
		`ods.setTNSEntryName("MyTNSAlias");`

Configuration Provider	Thin	`jdbc:oracle:thin:@config-<provider-type>://<parameters>` For example: • `jdbc:oracle:thin:@config-file://config.json` • `jdbc:oracle:thin:@config-https://myserver/config/myapp?key=dev` Refer to "the oracle.jdbc.OracleDriver Class and the oracle.jdbc.spi.OracleConfigurationProvider Interface for more details

8.2.5 Thin-style Service Name Syntax

Thin-style service names are supported only by the JDBC Thin driver. The syntax is:

```
@host_name:port_number/service_name
```

For example:

```
jdbc:oracle:thin:HR/<password>@localhost:5221/orcl
```


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> **Note**
>
> The JDBC Thin driver supports only the TCP/IP protocol.

8.2.6 Support for Easy Connect Plus

Oracle Database Release 19c JDBC driver introduced enhancements to the EasyConnect URL with many capabilities and this new enhanced Easy Connection URL is called Easy Connect Plus.

The EasyConnect URL supported simplified connection strings and the TCP transfer protocol. The goal of the enhancement to the EasyConnect URL is to simplify the client-side deployment and configuration, while connecting to the database. This enhancement can eliminate the need of using the `tnsnames.ora` file and you do not need to specify the `TNS_ADMIN` environment variable. The main features of Easy Connect Plus are the following:

- Support for TCPS Protocol
- Support for Multiple Hosts and Ports
- Support to Pass Connection Properties in the Connection String

8.2.6.1 Support for TCPS Protocol

The EasyConnect URL supported only the TCP transport protocol. However, the Easy Connect Plus supports both TCP and TCPS protocols. This enhancement simplifies the client configurations to Oracle Database Cloud Services that mandate TCPS connections.

For example, if you have a EasyConnect URL in the following format:

```
jdbc:oracle:thin:@(DESCRIPTION=
(ADDRESS=(PROTOCOL=tcps)(HOST=salesserver1)(PORT=1521))
(CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))
```

Then, the Easy Connect Plus URL will be:

```
jdbc:oracle:thin:@tcps:salesserver1:1521/sales.us.example.com
```

8.2.6.2 Support for LDAP and LDAPS

Starting from Oracle Database Release 23ai, the Easy Connect Plus URL supports LDAP and LDAPS protocols.

Syntax

The syntax follows a combination of the LDAP URL syntax and the Easy Connect Plus syntax:

```
ldap[s]://host[:port]/name[,context]?[parameter=value{&parameter=value}]
```


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For example:

```
sqlplus "<user_name>/<password>@ldaps://<host_name>/test?
DIRECTORY_SERVER_TYPE=oid&WALLET_LOCATION=/oracle/network/admin
&AUTHENTICATE_BIND=true&AUTHENTICATE_BIND_METHOD=LDAPS_SIMPLE_AUTH"
```

Parameters

The following table discusses the parameters used in the syntax:

Parameter Name	Description	Default Value
`host`	Specifies the host name. It is a compulsory parameter.	Not applicable
`name`	Specifies the alias name to be resolved. It is a compulsory parameter.	Not applicable
`port`	Specifies the port to be used. It is an optional parameter.	389 for LDAP and 636 for LDAPS
`context`	Specifies the context to be used. It is an optional parameter.	`cn=OracleContext`
`directory_server_type`	Specifies the directory server type to be used. The supported values are Oracle Internet Directory (OID), Oracle Unified Directory (OUD), and Active Directory (AD). It is an optional parameter.	OID
`wallet_location`	Specifies the wallet location to be used. It is an optional parameter.	Not applicable
`authenticate_bind`	Specifies whether LDAP adapter should use a wallet for authentication or not. Can be `true` or `false`. It is an optional parameter.	`false`
`authenticate_bind_method`	Specifies the authentication method to be used. The values can be either `LDAPS_SIMPLE_AUTH` or `NONE`. It is an optional parameter.	`NONE`

The `directory_server_type`, `wallet_location`, `authenticate_bind`, and `authenticate_bind_method` are position independent.

8.2.6.3 Support for Multiple Hosts and Ports

Using Easy Connect Plus, you can specify a comma-separated list of hosts.

The EasyConnect URL allowed only single host name and single port. But, Easy Connect Plus allows specifying multiple hosts and multiple ports in the connection string, which can be used to connect to a database with load balancing turned on. This enhanced Easy Connect syntax, using multiple hosts and ports, is as follows:

```
[[protocol:]//]host1{,host12}[:port1]{,host2:port2}{;host1{,host12}[:port1]}
[/[service_name][:server][/instance_name]][?
parameter_name=value{&parameter_name=value}]
```


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> **See Also**
>
> Support for Easy Connect Plus

For example, if you want to specify two hosts with a single port number in the connection using the following EasyConnect URL:

```
jdbc:oracle:thin:@(DESCRIPTION=
(ADDRESS_LIST= (LOAD_BALANCE=ON) (ADDRESS=(PROTOCOL=tcp)(HOST=salesserver1)
(PORT=1521)) (ADDRESS=(PROTOCOL=tcp)(HOST=salesserver2)(PORT=1521)))
(CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))
```

Then, the Easy Connect Plus URL will be the following:

```
jdbc:oracle:thin:@tcp:salesserver1,salesserver2:1521/sales.us.example.com
```

Again, if you want to specify multiple hosts as a list, where each list follows its own port number, using the following EasyConnect URL:

```
jdbc:oracle:thin:@(DESCRIPTION= (ADDRESS_LIST= (LOAD_BALANCE=ON)
(ADDRESS=(PROTOCOL=tcp)(HOST=salesserver1)(PORT=1521)) (ADDRESS=(PROTOCOL=tcp)
(HOST=salesserver2)(PORT=1522))
(ADDRESS=(PROTOCOL=tcp)(HOST=salesserver3)(PORT=1522)))
(CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))
```

Then, the Easy Connect Plus URL will be the following:

```
jdbc:oracle:thin:@tcp:salesserver1:1521,salesserver2,salesserver3:1522/
sales.us.example.com
```

8.2.6.4 Support to Pass Connection Properties in the Connection String

Easy Connect Plus supports specification of connection properties as name-value pairs in the connection URL. After the ? delimiter, Easy Connect Plus supports a list of parameters as name-value pairs, which can be optionally specified.

Remember the following points while specifying the name-value pairs:

- Use a question mark sign (?) to indicate the start of the name-value pairs and an ampersand sign (&) as a delimiter between each name-value pair.
- Specify the entire connection string as a single string.
- Use the backslash (\) escape character if there are any special characters in the value.
- Place white spaces within double-quotes if they are required as part of the value because leading and trailing white spaces are ignored within the parameter values.

The following table lists a few of the supported parameters:

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Parameter Name	Old URL Example	New URL Example
wallet_location	jdbc:oracle:thin:@(DESCRIPTION= (ADDRESS=(PROTOCOL=tcps) (HOST=salesserver1) (PORT=1521)) (CONNECT_DATA=(SERVICE_NAME=sales.us.example.com))	jdbc:oracle:thin:@tcps:salesserver1.com:1521/sales.us.example.com?wallet_location=/Users/jsmith/DBCloudService/wallet_JDBCTEST&oracle.net.ssl_server_cert_dn=\"CN=salesserver2.com.com,OU=Oracle BMCS US,O=Oracle Corporation,L=Redwood City,ST=California,C=US\"" ;
ssl_server_dn_match		
ssl_server_cert_dn	jdbc:oracle:thin:@(DESCRIPTION= (ADDRESS=(PROTOCOL=tcps) (HOST=salesserver1) (PORT=1521)) (SECURITY= (SSL_SERVER_DN_MATCH=TRUE) (SSL_SERVER_CERT_DN=cn=sales,cn=OracleContext,dc=us,dc=example,dc=com)) (CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))	jdbc:oracle:thin:@tcps:salesserver1:1521/sales.us.example.com?ssl_server_cert_dn="cn=sales,cn=OracleContext,dc=us,dc=example,dc=com"
https_proxy and https_proxy_port	jdbc:oracle:thin:@(DESCRIPTION= (ADDRESS=(PROTOCOL=tcps) (HOST=salesserver1) (PORT=1521) (https_proxy=www-proxy.mycompany.com) (https_proxy_port=80)) (CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))	jdbc:oracle:thin:@tcps:salesserver1:1521/sales.us.example.com?https_proxy=www-proxy.mycompany.com&https_proxy_port=80
connect_timeout	jdbc:oracle:thin:@(DESCRIPTION= (retry_count=3) (connect_timeout=60) (transport_connect_timeout=30) (ADDRESS=(PROTOCOL=tcp) (HOST=salesserver1) (PORT=1521)) (CONNECT_DATA=(SERVICE_NAME=sales.us.example.com)))	jdbc:oracle:thin:@tcps:salesserver1:1521/sales.us.example.com?connect_timeout=60&transport_connect_timeout=30&retry_count=3

The list of supported keywords under DESCRIPTION is as follows:

- ENABLE
- FAILOVER
- LOAD_BALANCE
- RECV_BUF_SIZE
- SEND_BUF_SIZE

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- SDU
- SOURCE_ROUTE
- RETRY_COUNT
- RETRY_DELAY
- CONNECT_TIMEOUT
- TRANSPORT_CONNECT_TIMEOUT

> **Note**
>
> - When your application uses a SOCKS proxy to connect to Oracle Database (for example, a Bastion in the Oracle Cloud), then the value of the TRANSPORT_CONNECT_TIMEOUT parameter is ignored.
> - Starting from Oracle Database Release 23ai, the default value of the TRANSPORT_CONNECT_TIMEOUT parameter is 20 seconds.

8.2.7 Support for Delay in Connection Retries

The RETRY_DELAY connection attribute specifies the delay between connection retries in seconds by default. Starting from Oracle Database Release 23ai, the default value of this parameter is 1 second.

Starting from Oracle Database Release 21c, you can also specify the delay in milliseconds and minutes, using the following units:

- ms (milliseconds)
- s (seconds)
- minutes (m)

The following code snippet shows how to use this attribute:

```
(DESCRIPTION_LIST=
  (DESCRIPTION=
   (CONNECT_TIMEOUT=10)(RETRY_COUNT=3)(RETRY_DELAY=800ms)
   (ADDRESS_LIST=
    (ADDRESS=(PROTOCOL=tcp)(HOST=myhost1)(PORT=1521))
    (ADDRESS=(PROTOCOL=tcp)(HOST=myhost2)(PORT=1521)))
   (CONNECT_DATA=(SERVICE_NAME=example1.com)))
  (DESCRIPTION=
   (CONNECT_TIMEOUT=60)(RETRY_COUNT=1)(RETRY_DELAY=5s)
   (ADDRESS_LIST=
    (ADDRESS=(PROTOCOL=tcp)(HOST=myhost3)(PORT=1521))
    (ADDRESS=(PROTOCOL=tcp)(HOST=myhost4)(PORT=1521)))
   (CONNECT_DATA=(SERVICE_NAME=example2.com))))
```

8.2.8 TNSNames Alias Syntax

You can find the available TNSNAMES entries listed in the tnsnames.ora file on the client computer from which you are connecting. On Windows, this file is located in the *ORACLE_HOME*\NETWORK\ADMIN directory. On UNIX systems, you can find it in the *ORACLE_HOME* directory or the directory indicated in your TNS_ADMIN environment variable.

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For example, if you want to connect to the database on host `myhost` as user `HR` with password `hr` that has a `TNSNAMES` entry of `MyHostString`, then write the following:

```
OracleDataSource ods = new OracleDataSource();
ods.setTNSEntryName("MyTNSAlias");
ods.setUser("HR");
ods.setPassword("hr");
ods.setDriverType("oci");
Connection conn = ods.getConnection();
```

The `oracle.net.tns_admin` system property must be set to the location of the `tnsnames.ora` file so that the JDBC Thin driver can locate the `tnsnames.ora` file. For example:

```
System.setProperty("oracle.net.tns_admin", "c:\\Temp");
String url = "jdbc:oracle:thin:@tns_entry";
```

> **Note**
>
> When using `TNSNames` with the JDBC Thin driver, you must set the `oracle.net.tns_admin` property to the directory that contains your `tnsnames.ora` file.
>
> ```
> java -Doracle.net.tns_admin=$ORACLE_HOME/network/admin
> ```

8.2.9 LDAP Syntax

This section describes the database specifiers that you can use with LDAP servers.

An example of database specifier using the Lightweight Directory Access Protocol (LDAP) syntax is as follows:

```
"jdbc:oracle:thin:@ldap:ldap.example.com:7777/sales,cn=OracleContext,dc=com"
```

When using TLS, change this syntax to the following:

```
"jdbc:oracle:thin:@ldaps:ldap.example.com:7777/sales,cn=OracleContext,dc=com"
```

> **Note**
>
> The JDBC Thin driver can use LDAP over TLS to communicate with Oracle Internet Directory if you substitute `ldap:` with `ldaps:` in the database specifier. The LDAP server must be configured to use TLS. If it is not, then the connection attempt will hang.

The JDBC Thin driver supports failover of a list of LDAP servers during the service name resolution process, without the need for a hardware load balancer. Also, client-side load balancing is supported for connecting to LDAP servers. A list of space separated LDAP URLs syntax is used to support failover and load balancing.

When a list of LDAP URLs is specified, both failover and load balancing are enabled by default. You can use the `oracle.net.ldap_loadbalance` connection property to disable load balancing, and the `oracle.net.ldap_failover` connection property to disable failover.

The following example shows failover with client-side load balancing disabled:

```
Properties prop = new Properties();
String url = "jdbc:oracle:thin:@ldap:ldap1.example.com:3500/
```


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```
cn=salesdept,cn=OracleContext,dc=com/salesdb" +
"ldap:ldap2.example.com:3500/cn=salesdept,cn=OracleContext,dc=com/salesdb " +
"ldap:ldap3.example.com:3500/cn=salesdept,cn=OracleContext,dc=com/salesdb";

prop.put("oracle.net.ldap_loadbalance", "OFF" );
OracleDataSource ods = new OracleDataSource();
ods.setURL(url);
ods.setConnectionProperties(prop);
```

The JDBC Thin driver supports LDAP non-anonymous bind. A set of JNDI environment properties, which contains authentication information, can be specified for a data source. If an LDAP server is configured as not to allow anonymous bind, then you must provide the authentication information to connect to the LDAP server. The following example shows a simple clear-text password authentication:

```
String url = "jdbc:oracle:thin:@ldap:ldap.example.com:7777/
sales,cn=salesdept,cn=OracleContext,dc=com";

Properties prop = new Properties();
prop.put("oracle.net.ldap.security.authentication", "simple");
prop.put("oracle.net.ldap.security.principal","cn=salesdept,cn=OracleContext,dc=com");
prop.put("oracle.net.ldap.security.credentials", "mysecret");

OracleDataSource ods = new OracleDataSource();
ods.setURL(url);
ods.setConnectionProperties(prop);
```

In the preceding example, as JDBC passes down the three properties to JNDI, the authentication mechanism chosen by client is consistent with how these properties are interpreted by JNDI. For example, if the client specifies authentication information without explicitly specifying the `java.naming.security.authentication` property, then the default authentication mechanism is `simple`.

Starting from Oracle Database Release 21c, you can specify the location of the wallet that the driver uses for TLS negotiation with the LDAP server. You can add the user name and the password used for authentication to the wallet secret store.

See Also

JDBC Java API Reference

8.2.9.1 Support for OpenLDAP

Starting from Oracle Database Release 21c, the JDBC Thin driver supports OpenLDAP.

See Also

The OpenLDAP Main Page for more information about OpenLDAP

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9

JDBC Client-Side Security Features

This chapter discusses support for IAM authentication for Autonomous Database, login authentication, network encryption and integrity with respect to features of the Oracle Advanced Security options in the JDBC OCI and the JDBC Thin drivers.

> **Note**
>
> - This discussion is not relevant to the server-side internal driver because all communication through server-side internal driver is completely internal to the server.
> - Using `SHA-1` (Secure Hash Algorithm 1) with the parameters `SQLNET.CRYPTO_CHECKSUM_TYPES_CLIENT` and `SQLNET.CRYPTO_CHECKSUM_TYPES_SERVER` is deprecated in this release, and can be desupported in a future release. Using `SHA-1` ciphers with `DBMS_CRYPTO` is also deprecated (`HASH_SH1`, `HMAC_SH1`). Instead of using `SHA1`, Oracle recommends that you start using a stronger `SHA-2` cipher in place of the `SHA-1` cipher.

Oracle Advanced Security, previously known as the Advanced Networking Option (ANO) or Advanced Security Option (ASO), provides industry standards-based network encryption, network integrity, third-party authentication, single sign-on, and access authorization. Both the JDBC OCI and JDBC Thin drivers support all the Oracle Advanced Security features.

> **Note**
>
> If you want to use the security policy file for JDBC `ojdbc.policy`, then you can download the file from the following link:
>
> http://www.oracle.com/technetwork/index.html
>
> The `ojdbc.policy` file contains the granted permissions that you need to run your application in control environment of the Java Security Manager. You can either use this file itself as your Java policy file, or get contents from this file and add the content in your Java policy file. This file contains permissions like:
>
> - A few mandatory permissions that are always required, for example, permission `java.util.PropertyPermission "user.name", "read";`
> - A few driver-specific permissions, for example, JDBC OCI driver needs permission `java.lang.RuntimePermission "loadLibrary.ocijdbc23";`
> - A few feature-based permissions, for example, permissions related to XA, XDB, FCF and so on
>
> You can set the system properties mentioned in the file or direct values for permissions as per your requirement.

This chapter contains the following sections:

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- Support for Token-Based Authentication for IAM
- Support for Token-Based Authentication for Azure AD
- Support for Oracle Advanced Security
- Support for Login Authentication
- Support for Strong Authentication
- Support for Network Encryption and Integrity
- Support for TLS
- Support for Kerberos
- Support for RADIUS
- Support for FIPS with Native Network Encryption
- Support for PEM in JDBC
- About Secure External Password Store

9.1 Support for Token-Based Authentication for IAM

In Oracle Database release 23ai, the JDBC Thin drivers provide enhanced support for Oracle Cloud Infrastructure (OCI) Identity Access Management (IAM).

While connecting to the database, the JDBC application provides a token to the database. The database verifies the token with a public key that it requests from the authentication service, and retrieves the corresponding user group membership information to find the database schema and role mappings to complete the user authorization to the database.

Additionally, the application sends a signed header, which proves that it possesses a private key that is paired to a public key embedded in the token. If both the token and the signature are valid, and there exists a mapping between the IAM user and a database user, then access to the database is granted to the JDBC application.

The token-based authentication is supported in the following ways:

9.1.1 Using the File System

When a database token is available on the file system, for example, if you use the Oracle Cloud Infrastructure Command-Line Interface (OCI CLI), then you can configure the JDBC driver to use this token for connecting to the Database.

You can use the `CONNECTION_PROPERTY_TOKEN_AUTHENTICATION` for this purpose, which can be specified in the following ways:

- As an `ojdbc.properties` file
- As a JVM system property
- As a parameter in the query section of a connection string
- With a `Properties` object passed to `OracleDataSource.setConnectionProperties(Properties)`
- As a parameter in the `SECURITY` section of an Oracle Net Descriptor

JDBC supports the following two types of connection strings, where you can specify this parameter:

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- As an Oracle Net descriptor, where you can specify the parameter as:

```
jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(HOST=dbhost)(PORT=1522)
(PROTOCOL=tcps))(SECURITY=(SSL_SERVER_DN_MATCH=ON)
(TOKEN_AUTH=OCI_TOKEN))(CONNECT_DATA=(SERVICE_NAME=my.example.com)))
```

- As a connection property, where you can specify the parameter as:

```
jdbc:oracle:thin:@tcps:dbhost:1522/my.example.com?
oracle.jdbc.tokenAuthentication=OCI_TOKEN&oracle.jdbc.tokenLocation
=″/path/to/my/token″
```

When `CONNECTION_PROPERTY_TOKEN_AUTHENTICATION` is set to `OCI_TOKEN`, then the `CONNECTION_PROPERTY_TOKEN_LOCATION` specifies the file system path, from where the driver obtains the access tokens. The default location is `$HOME/.oci/db-token/`. You can set this property to a different value to specify a nondefault location. The path specified by this property must be a directory containing files named `token` and `oci_db_key.pem`.

> **Note**
>
> - If an Oracle Net Descriptor style URL includes the `TOKEN_LOCATION` parameter, then the value of that parameter takes precedence over a value defined by `CONNECTION_PROPERTY_TOKEN_LOCATION`.
> - The token file must contain a JSON Web Token (JWT) on a single line of UTF-8 encoded text. The JWT format is specified by RFC 7519.
> - The token location must also contain a private key file named `oci_db_key.pem`. The private key file must use the PEM format and contain the base64 encoding of an RSA private key in the PKCS#8 encoding

You can also set the connection property `CONNECTION_PROPERTY_TOKEN_AUTHENTICATION` (`oracle.jdbc.tokenAuthentication`) to `OAUTH` and the connection property `CONNECTION_PROPERTY_TOKEN_LOCATION` (`oracle.jdbc.tokenLocation`) to point to the bearer token on the file system. There is no default location set in this case, so you must set the location to either of the following:

- A directory, in which case, the driver loads a file named `token`
- A fully qualified file name

You can perform this in the following ways:

- **Configuring the `ojdbc.properties` file**

```
# Enable the OAUTH authentication mode
oracle.jdbc.tokenAuthentication=OAUTH
# Specify the location of the Bearer token location
oracle.jdbc.tokenLocation=/home/user1/mytokens/jwtbearertoken
```

- **Using the JDBC URL**

```
jdbc:oracle:thin:@tcps:adb.mydomain.oraclecloud.com:1522/
xyz.adb.oraclecloud.com?
```


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```
oracle.jdbc.tokenAuthentication=OAUTH&oracle.jdbc.tokenLocation=/home/user/
token
```

- **Using the TNS format for a JDBC URL**:

```
jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=TCPS)(PORT=1521)
(HOST=adb.mydomain.oraclecloud.com))(CONNECT_DATA=
(SERVICE_NAME=xyz.adb.oraclecloud.com))(SECURITY=(TOKEN_AUTH=OAUTH)
(TOKEN_LOCATION=/home/user1/mytokens/jwtbearertoken)))"
```

9.1.2 Using the oracle.jdbc.accessToken Connection Property

Set the `CONNECTION_PROPERTY_ACCESS_TOKEN (oracle.jdbc.accessToken)` to the access token value.

You can perform this in the following ways:

> **Note**
>
> You must enclose the token value with double quotation marks ("") to escape the equal signs (=) that may appear in the token value.

- **Using the JDBC URL**

```
jdbc:oracle:thin:@tcps:adb.mydomain.oraclecloud.com:1522/
xyz.adb.oraclecloud.com?oracle.jdbc.accessToken="ey...5c"
```

- **Using the Descriptor URL**

```
jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcps)(HOST=mydomain.com)
(PORT=5525))
      (CONNECT_DATA=(SERVICE_NAME=myservice.com)))?
        oracle.jdbc.accessToken="ey...5c"
```

- **Configuring the `ojdbc.properties` File**

```
# Enable the OAUTH authentication mode
oracle.jdbc.accessToken="ey...5c"
```

Or,

```
# Enable the OAUTH authentication mode
oracle.jdbc.accessToken=${DATABASE_ACCESS_TOKEN}
```

Where, the access token is the value of the `DATABASE_ACCESS_TOKEN` environment variable.

> **Note**
>
> You do not need to set `oracle.jdbc.tokenAuthentication=OAUTH` as the driver automatically sets the `OAUTH` mode, when the access token is provided.

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9.1.3 Using the OracleConnectionBuilder Interface

Call the `OracleConnectionBuilder.accessToken` method for authentication with a database access token. This method accepts a token value that the application obtains from the authentication service.

If you pass a token using this method, then it overrides the connection string setting of `TOKEN_AUTH=OCI_TOKEN`, which means that JDBC does not read the token from the file system as it typically does. Instead, JDBC uses the `AccessToken` object provided to the `accessToken` method.

In this case, JDBC also generates a signature using the private key and sends it to the Database along with the IAM database access token. First, the Database verifies the token with the public signing key from IAM. Then, it verifies the JDBC-generated signature by decrypting it with a public key that is embedded in the token. If the decrypted signature is valid, then it proves that JDBC possesses the private key.

A single instance of the `OracleDataSource` class, configured with a single URL, creates instances of the `OracleConnectionBuilder` interface. These instances support traditional authentication with O5Logon, while also supporting token-based authentication. The application then calls the methods to configure a user and a password, or calls methods to configure a token. However, it is invalid to configure this builder with both a token and with a user name or a password. If both the `accessToken` method and the `password` or `user` methods are invoked with non-null values, then a `SQLException`, indicating an invalid configuration, is thrown when creating a connection with this builder.

9.1.4 Using the OracleDataSource Class

Call the `OracleCommonDataSource.setTokenSupplier(AccessToken accessToken)` method for authentication with a database access token.

This method sets a supplier function that generates an access token when creating a connection with this `DataSource`. The supplier function is invoked each time this `DataSource` creates a connection. Instances of access tokens, which are generated by the supplier, must represent a token type that is supported by Oracle Database for client authentication. The supplier must be thread safe.

> **Note**
>
> Use the `AccessToken.createJsonWebTokenCache(Supplier)` method to create a thread safe Supplier that caches tokens from a user defined Supplier.

It is invalid to configure this `DataSource` with both a token supplier and with a user name or password. If you invoke the `setUser(String)`, `setPassword(String)`, `setConnectionProperties(java.util.Properties)`, or `setConnectionProperty(String, String)` methods to configure this `DataSource` with a user name or a password, and also invoke the `setTokenSuppliersetTokenSupplier(AccessToken accessToken)` method to configure a token supplier, then a `SQLException` indicating an invalid configuration is thrown, when creating a connection with this `DataSource`.

The access tokens are ephemeral in nature and expire within an hour or less. So, use the `Supplier` type that enables an instance of the `OracleDataSource` class to obtain a newly generated token, each time it creates a connection. The `Supplier` can generate the same token multiple times, until the expiration time of that token passes. After the expiration time of a

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token is over, the `Supplier` must no longer generate that token, and instead begin to generate a new token with a later expiration time.

See Also

- Authenticating and Authorizing IAM Users for Oracle Autonomous Databases
- About TCP/IP with TLS Protocol

9.2 Support for Token-Based Authentication for Azure AD

In this release of Oracle Database, the JDBC Thin drivers provide support for Azure Active Directory (Azure AD) OAuth2 access tokens.

While connecting to the database, the JDBC application provides a token to the database. The database verifies the token with a public key that it requests from the authentication service, and retrieves the corresponding user group membership information to find the database schema and role mappings to complete the user authorization to the database.

The token-based authentication is supported in the following ways:

9.2.1 Using the File System

When a database token is available on the file system, then you can configure the JDBC driver to use this token for connecting to the Database.

You can use the `CONNECTION_PROPERTY_TOKEN_AUTHENTICATION` for this purpose, which can be specified in the following ways:

- As an `ojdbc.properties` file
- As a JVM system property
- As a parameter in the query section of a connection string
- With a `Properties` object passed to `OracleDataSource.setConnectionProperties(Properties)`
- As a parameter in the `SECURITY` section of an Oracle Net Descriptor

JDBC supports the following two types of connection strings, where you can specify this parameter:

- As an Oracle Net descriptor, where you can specify the parameter as:

```
jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(HOST=dbhost)(PORT=1522)
(PROTOCOL=tcps))(SECURITY=(SSL_SERVER_DN_MATCH=ON)
(TOKEN_AUTH=OAUTH)(TOKEN_LOCATION=/path/to/my/token)))
```

- As a connection property, where you can specify the parameter as:

```
jdbc:oracle:thin:@tcps:dbhost:1522/my.example.com?
oracle.jdbc.tokenAuthentication=OAUTH&oracle.jdbc.tokenLocation
=″/path/to/my/token″
```

When `CONNECTION_PROPERTY_TOKEN_AUTHENTICATION` is set to `OAUTH`, then the `CONNECTION_PROPERTY_TOKEN_LOCATION` specifies the file system path, from where you can

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obtain the access tokens. There is no default location in this case. You must set the token location, which can be a directory containing the token in a filed named `token`. For instance, if the directory `mytokendirectory` contains the file named `token`, then you set the token location in the following way:

```
/path/to/mytokendirectory
```

> **Note**
>
> - If an Oracle Net Descriptor style URL includes the `TOKEN_LOCATION` parameter, then the value of that parameter takes precedence over a value defined by `CONNECTION_PROPERTY_TOKEN_LOCATION`.
> - The token file must contain a JSON Web Token (JWT) on a single line of UTF-8 encoded text. The JWT format is specified by RFC 7519.

You can also set the connection property `CONNECTION_PROPERTY_TOKEN_AUTHENTICATION` (`oracle.jdbc.tokenAuthentication`) to `OAUTH` and the connection property `CONNECTION_PROPERTY_TOKEN_LOCATION` (`oracle.jdbc.tokenLocation`) to point to the bearer token on the file system. There is no default location set in this case, so you must set the location to either of the following:

- A directory, in which case, the driver loads a file named `token`
- A fully qualified file name

You can perform this in the following ways:

- **Configuring the `ojdbc.properties` file**

  ```
  # Enable the OAUTH authentication mode
  oracle.jdbc.tokenAuthentication=OAUTH
  # Specify the location of the Bearer token location
  oracle.jdbc.tokenLocation=/home/user1/mytokens/jwtbearertoken
  ```

- **Using the JDBC URL**

  ```
  jdbc:oracle:thin:@tcps:adb.mydomain.oraclecloud.com:1522/
  xyz.adb.oraclecloud.com?
  oracle.jdbc.tokenAuthentication=OAUTH&oracle.jdbc.tokenLocation=/home/user/
  token
  ```

- **Using the TNS format for a JDBC URL**:

  ```
  jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=TCPS)(PORT=1521)
  (HOST=adb.mydomain.oraclecloud.com))(CONNECT_DATA=
  (SERVICE_NAME=xyz.adb.oraclecloud.com))(SECURITY=(TOKEN_AUTH=OAUTH)
  (TOKEN_LOCATION=/home/user1/mytokens/jwtbearertoken)))"
  ```


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9.2.2 Using the oracle.jdbc.accessToken Connection Property

Set the `CONNECTION_PROPERTY_ACCESS_TOKEN` (`oracle.jdbc.accessToken`) to the access token value.

You can perform this in the following ways:

> **Note**
>
> You must enclose the token value with double quotation marks ("") to escape the equal signs (=) that may appear in the token value.

- **Using the JDBC URL**

```
jdbc:oracle:thin:@tcps:adb.mydomain.oraclecloud.com:1522/
xyz.adb.oraclecloud.com?oracle.jdbc.accessToken="ey...5c"
```

- **Using the Descriptor URL**

```
jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcps)(HOST=mydomain.com)
(PORT=5525))
      (CONNECT_DATA=(SERVICE_NAME=myservice.com)))?
        oracle.jdbc.accessToken="ey...5c"
```

- **Configuring the `ojdbc.properties` File**

```
# Enable the OAUTH authentication mode
oracle.jdbc.accessToken="ey...5c"
```

Or,

```
# Enable the OAUTH authentication mode
oracle.jdbc.accessToken=${DATABASE_ACCESS_TOKEN}
```

Where, the access token is the value of the `DATABASE_ACCESS_TOKEN` environment variable.

> **Note**
>
> You do not need to set `oracle.jdbc.tokenAuthentication=OAUTH` as the driver automatically sets the `OAUTH` mode, when the access token is provided.

9.2.3 Using the OracleConnectionBuilder Interface

Call the `OracleConnectionBuilder.accessToken` method for authentication with a database access token.

This method accepts a token value that the application obtains from the authentication service. If you pass a token using this method, then it overrides the connection string setting of `TOKEN_AUTH=OCI_TOKEN`then `TOKEN_AUTH=OAUTH`, which means that JDBC does not read the

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token from the file system as it typically does. Instead, JDBC uses the `AccessToken` object provided to the `accessToken` method.

A single instance of the `OracleDataSource` class, configured with a single URL, creates instances of the `OracleConnectionBuilder` interface. These instances support traditional authentication with O5Logon, while also supporting token-based authentication. The application then calls the methods to configure a user and a password, or calls methods to configure a token. However, it is invalid to configure this builder with both a token and with a user name or a password. If both the `accessToken` method and the `password` or `user` methods are invoked with non-null values, then a `SQLException`, indicating an invalid configuration, is thrown when creating a connection with this builder.

9.2.4 Using the OracleDataSource Class

Call the `OracleCommonDataSource.setTokenSupplier(AccessToken accessToken)` method for authentication with a database access token.

This method sets a supplier function that generates an access token when creating a connection with this `DataSource`. The supplier function is invoked each time this `DataSource` creates a connection. Instances of access tokens, which are generated by the supplier, must represent a token type that is supported by Oracle Database for client authentication. The supplier must be thread safe.

> **Note**
>
> Use the `AccessToken.createJsonWebTokenCache(Supplier)` method to create a thread safe Supplier that caches tokens from a user defined Supplier.

It is invalid to configure this `DataSource` with both a token supplier and with a user name or password. If you invoke the `setUser(String)`, `setPassword(String)`, `setConnectionProperties(java.util.Properties)`, or `setConnectionProperty(String, String)` methods to configure this `DataSource` with a user name or a password, and also invoke the `setTokenSuppliersetTokenSupplier(AccessToken accessToken)` method to configure a token supplier, then a `SQLException` indicating an invalid configuration is thrown, when creating a connection with this `DataSource`.

The access tokens are ephemeral in nature and expire within an hour or less. So, use the `Supplier` type that enables an instance of the `OracleDataSource` class to obtain a newly generated token, each time it creates a connection. The `Supplier` can generate the same token multiple times, until the expiration time of that token passes. After the expiration time of a token is over, the `Supplier` must no longer generate that token, and instead begin to generate a new token with a later expiration time.

> **See Also**
>
> - Use Azure Active Directory (Azure AD) with Autonomous Database
> - About TCP/IP with TLS Protocol

9.3 Support for Oracle Advanced Security

This section describes the following concepts:

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- Overview of Oracle Advanced Security
- JDBC OCI Driver Support for Oracle Advanced Security
- JDBC Thin Driver Support for Oracle Advanced Security

9.3.1 Overview of Oracle Advanced Security

Oracle Advanced Security provides the following security features:

- Network Encryption

  Sensitive information communicated over enterprise networks and the Internet can be protected by using encryption algorithms, which transform information into a form that can be deciphered only with a decryption key. For example, AES.

  To ensure network integrity during transmission, Oracle Advanced Security generates a cryptographically secure message digest. Starting from Oracle Database 12*c* Release 1 (12.1), the SHA-2 list of hashing algorithms are also supported and Oracle Advanced Security uses the following hashing algorithms to generate the secure message digest and includes it with each message sent across a network.

  This protects the communicated data from attacks, such as data modification, deleted packets, and replay attacks.

  The following code snippet shows how to calculate the checksum using any of the algorithms mentioned previously:

  ```
  prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES,
  "( SHA1)");
  prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL,
  "REQUIRED");
  ```

- Strong Authentication

  To ensure network security in distributed environments, it is necessary to authenticate the user and check their credentials. Password authentication is the most common means of authentication. Oracle Database enables strong authentication with Oracle authentication adapters, which support various third-party authentication services, including TLS with digital certificates. Oracle Database supports the following industry-standard authentication methods:

  – Kerberos
  – Remote Authentication Dial-In User Service (RADIUS)
  – Transport Layer Security (TLS)

> **See Also**
>
> *Oracle Database Security Guide*

9.3.2 JDBC OCI Driver Support for Oracle Advanced Security

If you are using the JDBC OCI driver, which presumes that you are running from a computer with an Oracle client installation, then support for Oracle Advanced Security and incorporated third-party features is fairly similar to the support provided by in any Oracle client situation. Your use of Advanced Security features is determined by related settings in the `sqlnet.ora` file on the client computer.

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> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), Oracle recommends you to use the configuration parameters present in the new XML configuration file `oraaccess.xml` instead of the OCI-specific configuration parameters present in the `sqlnet.ora` file. However, the configuration parameters present in the `sqlnet.ora` file are still supported.

The JDBC OCI driver attempts to use external authentication if you try connecting to a database without providing a password. The following are some examples using the JDBC OCI driver to connect to a database without providing a password:

TLS Authentication

The following code snippet shows how to use TLS authentication to connect to the database:

Example 9-1 Using TLS Authentication to Connect to the Database

```
import java.sql.*;
import java.util.Properties;

public class test
{
    public static void main( String [] args ) throws Exception
    {
        String url = "jdbc:oracle:oci:@"
         +"(DESCRIPTION=(ADDRESS=(PROTOCOL=tcps)(HOST=localhost)(PORT=5221))"
         +"(CONNECT_DATA=(SERVICE_NAME=orcl)))";
        Driver driver = new oracle.jdbc.OracleDriver();
        Properties props = new Properties();
        Connection conn = driver.connect( url, props );
        conn.close();
    }
}
```

Using a Data Source

The following code snippet shows how to use a data source to connect to the database:

Example 9-2 Using a Data Source to Connect to the Database

```
import java.sql.*;
import javax.sql.*;
import java.util.Properties;
import oracle.jdbc.pool.*;

public class testpool {
    public static void main( String args ) throws Exception
    { String url = "jdbc:oracle:oci:@" +"(DESCRIPTION=(ADDRESS=(PROTOCOL=tcps)
(HOST=localhost)(PORT=5221))"
 +"(CONNECT_DATA=(SERVICE_NAME=orcl)))";
    OracleConnectionPoolDataSource ocpds = new OracleConnectionPoolDataSource();
    ocpds.setURL(url);
    PooledConnection pc = ocpds.getPooledConnection();
    Connection conn = pc.getConnection();
    }
    }
```


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> **Note**
>
> The key exception to the preceding, with respect to Java, is that the Transport Layer Security (TLS) protocol is supported by the Oracle JDBC OCI drivers only if you use native threads in your application. This requires special attention, because green threads are generally the default.

9.3.3 JDBC Thin Driver Support for Oracle Advanced Security

The JDBC Thin driver cannot assume the existence of an Oracle client installation or the presence of the `sqlnet.ora` file.

Therefore, it uses a Java approach to support Oracle Advanced Security. Java classes that implement Oracle Advanced Security are included in the `ojdbc8.jar`, `ojdbc11.jar`, and `ojdbc17.jar` files. Security parameters for encryption and integrity, usually set in the `sqlnet.ora` file, are set using a Java `Properties` object or through system properties.

9.4 Support for Login Authentication

Basic login authentication through JDBC consists of user names and passwords, as with any other means of logging in to an Oracle server. Specify the user name and password through a Java properties object or directly through the `getConnection` method call. This applies regardless of which client-side Oracle JDBC driver you are using, but is irrelevant if you are using the server-side internal driver, which uses a special direct connection and does not require a user name or password.

Starting with Oracle Database 12*c* Release 1 (12.1.0.2), the Oracle JDBC Thin driver supports the `O7L_MR` client ability when you are running your application with a JDK such as JDK 8, which supports the `PBKDF2-SHA2` algorithm. If you are running an application with JDK 7, then you must add a third-party security provider that supports the `PBKDF2-SHA2` algorithm, otherwise the driver will not support the new `12a` password verifier that requires the `O7L_MR` client ability.

If you are using Oracle Database 12*c* Release 1 (12.1.0.2) with the `SQLNET.ALLOWED_LOGON_VERSION_SERVER` parameter set to `12a`, then keep the following points in mind:

- You must also use the 12.1.0.2 Oracle JDBC Thin driver and JDK 8 or JDK 7 with a third-party security provider that supports the `PBKDF2-SHA2` algorithm
- If you use an earlier version of Oracle JDBC Thin driver, then you will get the following error:

  ```
  ORA-28040: No matching authentication protocol
  ```

- If you use the 12.1.0.2 Oracle JDBC Thin driver with JDK 7, then also you will get the same error, if you do not add a third-party security provider that supports the `PBKDF2-SHA2` algorithm.

9.5 Support for Strong Authentication

Oracle Advanced Security enables Oracle Database users to authenticate externally. External authentication can be with RADIUS, Kerberos, Certificate-Based Authentication, Token Cards,

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and Smart Cards. This is called strong authentication. Oracle JDBC drivers provide support for the following strong authentication methods:

- Kerberos
- RADIUS
- TLS

> **See Also**
>
> *Oracle AI Database Net Services Reference*

9.6 Support for Network Encryption and Integrity

The section describes the support for network encryption and integrity.

> **Note**
>
> - Starting with Oracle Database 21c, older encryption and hashing algorithms are deprecated.
>
> The deprecated algorithms for `DBMS_CRYPTO` and native network encryption include MD4, MD5, DES, 3DES, and RC4-related algorithms as well as 3DES for Transparent Data Encryption (TDE). Removing older, less secure cryptography algorithms prevents accidental use of these algorithms. To meet your security requirements, Oracle recommends that you use more modern cryptography algorithms, such as the Advanced Encryption Standard (AES).
> - Oracle provides a patch that you can download to address necessary security enhancements that affect native network encryption environments in Oracle Database release 11.2 and later. This patch is available in My Oracle Support note 2118136.2.

> **See Also**
>
> *Oracle Database Security Guide*

This section describes the following concepts:

- Overview of JDBC Support for Data Encryption and Integrity
- JDBC OCI Driver Support for Encryption and Integrity
- JDBC Thin Driver Support for Encryption and Integrity
- Setting Encryption and Integrity Parameters in Java

9.6.1 Overview of JDBC Support for Network Encryption and Integrity

You can use Oracle Database and Oracle Advanced Security network encryption and integrity features in your Java database applications, depending on related settings in the server. When

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using the JDBC OCI driver, set parameters as you would in any Oracle client situation. When using the Thin driver, set parameters through a Java properties object.

Encryption is enabled or disabled based on a combination of the client-side encryption-level setting and the server-side encryption-level setting. Similarly, integrity is enabled or disabled based on a combination of the client-side integrity-level setting and the server-side integrity-level setting.

Encryption and integrity support the same setting levels, `REJECTED`, `ACCEPTED`, `REQUESTED`, and `REQUIRED`. Table 9-1 shows how these possible settings on the client-side and server-side combine to either enable or disable the feature. By default, remote OS authentication (through TCP) is disabled in the database for security reasons.

Table 9-1 Client/Server Negotiations for Encryption or Integrity

Client/Server Settings Matrix	Client Rejected	Client Accepted (default)	Client Requested	Client Required
Server Rejected	OFF	OFF	OFF	connection fails
Server Accepted (default)	OFF	OFF	ON	ON
Server Requested	OFF	ON	ON	ON
Server Required	connection fails	ON	ON	ON

Table 9-1 shows, for example, that if encryption is requested by the client, but rejected by the server, it is disabled. The same is true for integrity. As another example, if encryption is accepted by the client and requested by the server, it is enabled. The same is also true for integrity.

See Also

Oracle Database Security Guide for more information about network encryption and integrity features

Note

The term checksum still appears in integrity parameter names, but is no longer used otherwise. For all intents and purposes, checksum and integrity are synonymous.

9.6.2 JDBC OCI Driver Support for Encryption and Integrity

If you are using the JDBC OCI driver, which presumes an Oracle-client setting with an Oracle client installation, then you can enable or disable network encryption or integrity and set related

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parameters as you would in any Oracle client situation, through settings in the `sqlnet.ora` file on the client.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), Oracle recommends you to use the configuration parameters present in the new XML configuration file `oraaccess.xml` instead of the OCI-specific configuration parameters present in the `sqlnet.ora` file. However, the configuration parameters present in the `sqlnet.ora` file are still supported.

To summarize, the client parameters are shown in Table 9-2:

Table 9-2 OCI Driver Client Parameters for Encryption and Integrity

Parameter Description	Parameter Name	Possible Settings
Client encryption level	`SQLNET.ENCRYPTION_CLIENT`	`REJECTED ACCEPTED REQUESTED REQUIRED`
Client encryption selected list	`SQLNET.ENCRYPTION_TYPES_CLIENT`	`AES128`, `AES192`, `AES256`
Client integrity level	`SQLNET.CRYPTO_CHECKSUM_CLIENT`	`REJECTED ACCEPTED REQUESTED REQUIRED`
Client integrity selected list	`SQLNET.CRYPTO_CHECKSUM_TYPES_CLIENT`	`SHA-1`

9.6.3 JDBC Thin Driver Support for Encryption and Integrity

The JDBC Thin driver support for network encryption and integrity parameter settings parallels the JDBC OCI driver support discussed in the preceding section. You can set the corresponding parameters through a Java properties object that you can use while opening a database connection.

The default value for the encryption and integrity level is `ACCEPTED` for both the server side and the client side. This enables you to achieve the desired security level for a connection pair by configuring only one side of a connection, either the server side or the client side. This increases the efficiency of your program because if there are multiple Oracle clients connecting to an Oracle Server, then you need to change the encryption and integrity level to `REQUESTED` in the `sqlnet.ora` file only on the server side to turn on encryption or integrity for all connections. This saves time and effort because you do not have to change the settings for each client separately.

Following is the list of parameters for the JDBC Thin driver, which are defined in the `oracle.jdbc.OracleConnection` interface:

- The CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL Parameter
- The CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES Parameter
- The CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL Parameter
- The CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES Parameter
- The CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES Parameter

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> **Note**
>
> - Oracle Advanced Security support for the Thin driver is incorporated directly into the JDBC classes JAR file. So, there is no separate version for domestic and export editions. Only parameter settings that are suitable for an export edition are possible.

9.6.3.1 The CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL Parameter

The `CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL` parameter defines the level of security that the client uses to negotiate with the server.

The following table describes the attributes of this parameter:

Table 9-3 CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL Attributes

Attribute	Value
Parameter Type	String
Parameter Class	Static
Permitted Values	`REJECTED ACCEPTED REQUESTED REQUIRED`
Default Value	`ACCEPTED`
Syntax	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL,level);` where `prop` is an object of the `Properties` class
Example	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL,"REQUIRED");` where `prop` is an object of the `Properties` class

9.6.3.2 The CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES Parameter

The `CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES` parameter defines the encryption algorithm that you should use.

The following table describes the attributes of this parameter:

Table 9-4 CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES Attributes

Attribute	Description
Parameter Type	String
Parameter Class	Static
Permitted Values	`AES256` (AES 256-bit key), `AES192` (AES 192-bit key), `AES128` (AES 128-bit key),
Syntax	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES,algorithm);` where `prop` is an object of the `Properties` class

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Table 9-4 (Cont.) CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES Attributes

Attribute	Description
Example	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES, "( AES256, AES192 )");` where `prop` is an object of the `Properties` class

9.6.3.3 The CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL Parameter

The `CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL` parameter defines the level of security to negotiate with the server for data integrity.

The following table describes the attributes of this parameter:

Table 9-5 CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL Attributes

Attribute	Description
Parameter Type	String
Parameter Class	Static
Permitted Values	`REJECTED`; `ACCEPTED`; `REQUESTED`; `REQUIRED`
Default Value	`ACCEPTED`
Syntax	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL,`*`level`*`);` where `prop` is an object of the `Properties` class
Example	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL,"REQUIRED");` where `prop` is an object of the `Properties` class

9.6.3.4 The CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES Parameter

The `CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES` parameter defines the data integrity algorithm to be used.

The following table describes the attributes of this parameter.

Table 9-6 CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES Attributes

Attribute	Description
Parameter Type	String
Parameter Class	Static
Permitted Values	SHA1
Syntax	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES,` *`algorithm`*`);` where `prop` is an object of the `Properties` class

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Table 9-6 (Cont.) CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES Attributes

Attribute	Description
Example	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES,"( SHA1 )");` where `prop` is an object of the `Properties` class

9.6.3.5 The CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES Parameter

The `CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES` parameter determines the authentication service to be used.

The following table describes the attributes of this parameter:

Table 9-7 CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES Attributes

Attribute	Description
Parameter Type	String
Parameter Class	Static
Permitted Values	`RADIUS, KERBEROS5, BEQ, TCPS`
Syntax	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES,`*`authentication`*`);` where `prop` is an object of the `Properties` class
Example	`prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES,"( RADIUS, KERBEROS5,TCPS)")` where `prop` is an object of the `Properties` class

9.6.4 Setting Encryption and Integrity Parameters in Java

Use a Java properties object, that is, an instance of `java.util.Properties`, to set the network encryption and integrity parameters supported by the JDBC Thin driver.

The following example instantiates a Java properties object, uses it to set each of the parameters in Table 9-3, and then uses the properties object in opening a connection to the database:

```
...
Properties prop = new Properties();
prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVEL,
"REQUIRED");
prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPES,
"( AES256 )");
prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL,
"REQUESTED");
prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES,
"( SHA1 )");
```


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```
OracleDataSource ods = new OracleDataSource();
ods.setConnectionProperties(prop);
ods.setURL("jdbc:oracle:thin:@localhost:5221:main");
Connection conn = ods.getConnection();
...
```

The parentheses around the values encryption type and checksum type allow for lists of values. When multiple values are supplied, the server and the client negotiate to determine which value is to be actually used.

Example

Example 9-3 is a complete class that sets network encryption and integrity parameters before connecting to a database to perform a query.

> **Note**
>
> In the example, the string `REQUIRED` is retrieved dynamically through the functionality of the `AnoServices` and `Service` classes. You have the option of retrieving the strings in this manner or including them in the software code as shown in the previous examples.

Before running this example, you must turn on encryption in the `sqlnet.ora` file. For example, the following lines will turn on AES256, AES192, and AES128 for the encryption and SHA1 for the checksum:

```
SQLNET.ENCRYPTION_SERVER = ACCEPTED
SQLNET.CRYPTO_CHECKSUM_SERVER = ACCEPTED
SQLNET.CRYPTO_CHECKSUM_TYPES_SERVER = (SHA1)
SQLNET.ENCRYPTION_TYPES_SERVER = (AES256, AES192, AES128)
```

Example 9-3 Setting Network Encryption and Integrity Parameters

```
import java.sql.*;
import java.util.Properties;
import oracle.net.ano.AnoServices;
import oracle.jdbc.*;
import oracle.jdbc.pool.*;

public class DemoAESAndSHA1
{
  static final String USERNAME= "HR";
  static final String PASSWORD= "hr";
  static final String URL =
"jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)(HOST=localhost)
(PORT=5221))"
      +"(CONNECT_DATA=(SERVICE_NAME=orcl)))";

  public static final void main(String[] argv)
  {
    DemoAESAndSHA1 demo = new DemoAESAndSHA1();
    try
    {
      demo.run();
```


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```
    }catch(SQLException ex)
    {
      ex.printStackTrace();
    }
  }

  void run() throws SQLException
  {
    OracleDataSource ods = new OracleDataSource();
    Properties prop = new Properties();

    // We require the connection to be encrypted with either AES256 or AES192.
    // If the database does not accept such a security level, then the
connection attempt will fail.

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_LEVE
L, AnoServices.ANO_REQUIRED);

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_ENCRYPTION_TYPE
S, "( " + AnoServices.ENCRYPTION_AES256 + "," + AnoServices.ENCRYPTION_AES192
+ ")");

    // We also require the use of the SHA1 algorithm for network integrity
checking.

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_LEVEL,
 AnoServices.ANO_REQUIRED);

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_CHECKSUM_TYPES,
 "( " + AnoServices.CHECKSUM_SHA1 + " )");
    prop.setProperty("user", DemoAESAndSHA1.USERNAME);
    prop.setProperty("password", DemoAESAndSHA1.PASSWORD);
    ods.setConnectionProperties(prop);
    ods.setURL(DemoAESAndSHA1.URL);
    OracleConnection oraConn = (OracleConnection) ods.getConnection();
    System.out.println("Connection created! Encryption algorithm is: " +
oraConn.getEncryptionAlgorithmName() + ", network integrity algorithm is: " +
oraConn.getDataIntegrityAlgorithmName());
    oraConn.close();
  }

}
```

9.7 Support for TLS

This section describes the following topics:

- Overview of JDBC Support for TLS
- About Managing Certificates and Wallets
- About Keys and certificates containers
- Database Connectivity with TLS Version 1.3 Using the JDBC Thin Driver
- Automatic TLS Connection Configuration

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- Support for Default TLS Context
- SNI Support for TLS Connections
- Support for Key Store Service

9.7.1 Overview of JDBC Support for TLS

Oracle Database 23ai provides support for the Transport Layer Security (TLS) protocol. TLS is a widely used industry standard protocol that provides secure communication over a network. TLS provides authentication, data encryption, and data integrity. It provides a secure enhancement to the standard TCP/IP protocol, which is used for Internet communication.

TLS uses digital certificates that comply with the X.509v3 standard for authentication and a public and private key pair for encryption. TLS also uses secret key cryptography and digital signatures to ensure privacy and integrity of data. When a network connection over TLS is initiated, the client and server perform a TLS handshake that includes the following steps:

- Client and server negotiate about the cipher suites to use. This includes deciding on the encryption algorithms to be used for data transfer.
- Server sends its certificate to the client, and the client verifies that the certificate was signed by a trusted certification authority (CA). This step verifies the identity of the server.
- If client authentication is required, the client sends its own certificate to the server, and the server verifies that the certificate was signed by a trusted CA.
- Client and server exchange key information using public key cryptography. Based on this information, each generates a session key. All subsequent communications between the client and the server is encrypted and decrypted by using this set of session keys and the negotiated cipher suite.

TLS Terminology

The following terms are commonly used in the TLS context:

- **Certificate**: A certificate is a digitally signed document that binds a public key with an entity. The certificate can be used to verify that the public key belongs to that individual.
- **Certification authority**: A certification authority (CA), also known as certificate authority, is an entity which issues digitally signed certificates for use by other parties.
- **Cipher suite**: A cipher suite is a set of cryptographic algorithms and key sizes used to encrypt data sent over a TLS-enabled network.
- **Private key**: A private key is a secret key, which is never transmitted over a network. The private key is used to decrypt a message that has been encrypted using the corresponding public key. It is also used to sign certificates. The certificate is verified using the corresponding public key.
- **Public key**: A public key is an encryption key that can be made public or sent by ordinary means such as an e-mail message. The public key is used for encrypting the message sent over TLS. It is also used to verify a certificate signed by the corresponding private key.
- **Key Store or Wallet**: A wallet is a password-protected container that is used to store authentication and signing credentials, including private keys, certificates, and trusted certificates required by TLS.
- **Security Provider**: A Java implementation that provides some functionality related to security. A provider is responsible for decoding a key store file.

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- **Key Store Service (KSS)**: A component of Oracle Platform Security services. KSS enables a key store to be referenced as a URI with `kss://` scheme (rather than a file name).

Java Version of TLS

The Java Secure Socket Extension (JSSE) provides a framework and an implementation for a Java version of the TLS protocol. JSSE provides support for data encryption, server and client authentication, and message integrity. It abstracts the complex security algorithms and handshaking mechanisms and simplifies application development by providing a building block for application developers, which they can directly integrate into their applications. JSSE is integrated into Java Development Kit (JDK) 1.4 and later, and supports TLS version 2.0 and 3.0.

Oracle strongly recommends that you have a clear understanding of the JavaTM Secure Socket Extension (JSSE) framework before using TLS in the Oracle JDBC drivers.

The JSSE standard application programming interface (API) is available in the `javax.net`, `javax.net.ssl`, and `javax.security.cert` packages. These packages provide classes for creating and configuring sockets, server sockets, TLS sockets, and TLS server sockets. The packages also provide a class for secure HTTP connections, a public key certificate API compatible with JDK1.1-based platforms, and interfaces for key and trust managers.

TLS works the same way, as in any networking environment, in Oracle Database 18c.

> **Note**
>
> In order to use JSSE in your program, you must have clear understanding of JavaTM Secure Socket Extension (JSSE) framework.

9.7.2 About Managing Certificates and Wallets

To establish a TLS connection with a JDBC client, either Thin or OCI, the Oracle Database server sends its certificate, which is stored in its wallet. The client may or may not need a certificate or wallet, depending on the server configuration.

> **Note**
>
> - The Oracle JDBC Thin driver uses the JSSE framework to create a TLS connection. It uses the default provider (*SunJSSE*) to create a TLS context, but you can provide your own provider.
> - You do not need a certificate for the client, unless the `SSL_CLIENT_AUTHENTICATION` parameter is set on the server.

This client certificate may be in an Oracle wallet, Microsoft Certificate Store (MCS), Java key store, or Linux `certs` folder (`/etc/ssl/certs`). When multiple certificates are present, then the correct client certificate for a connection is pulled by the client in either of the following two ways:

- **Using the certificate alias:** In this case, the client certificate can be uniquely identified by its alias. Starting from Oracle Database 23ai Release, you can configure the alias using the `SSL_CERTIFICATE_ALIAS SECURITY` parameter in the connection string.

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- **Using the certificate thumbprint:** In this case, the client certificate can be uniquely identified by its thumbprint. Starting from Oracle Database 23ai Release, you can set the thumbprint using the `SSL_CERTIFICATE_THUMBPRINT SECURITY` parameter in the connection string. You can also set it using either the `SSL_CERTIFICATE_THUMBPRINT` parameter of the Easy Connect Plus URL or the `CONNECTION_PROPERTY_THIN_SSL_CERTIFICATE_THUMBPRINT` JDBC property.

See Also

- SSL_CLIENT_AUTHENTICATION Parameter
- CONNECTION_PROPERTY_THIN_SSL_CERTIFICATE_ALIAS
- SSL_CERTIFICATE_THUMBPRINT Parameter
- CONNECTION_PROPERTY_THIN_SSL_CERTIFICATE_THUMBPRINT

9.7.3 About Keys and certificates containers

Java clients can use multiple types of containers such as Oracle wallets, JKS, PKCS12, and so on, as long as a provider is available. For Oracle wallets, *OraclePKI* provider must be used because the PKCS12 support provided by *SunJSSE* provider does not support all the features of PKCS12. In order to use the `OraclePKI` provider, you must have the `oraclepki.jar` file under the `$ORACLE_HOME/jlib` directory.

9.7.4 Database Connectivity with TLS Version 1.3 Using the JDBC Thin Driver

This section describes the steps to configure the Oracle JDBC thin driver to connect to the Database using TLS v1.3.

Note

- Starting from JDK 8 (JDK 8u341), TLS 1.3 version is auto enabled.
- Oracle recommends not to configure the protocol version and let the JDK implementation choose the most secure version of the protocol. If you must choose the protocol version for a specific need, then you can achieve it in one of the following ways:
  - Using connection property: Set `CONNECTION_PROPERTY_THIN_SSL_VERSION={1.3, 1.2}`
  - Using system property: Set `-Doracle.net.ssl_version="1.3", "1.2"`
  - Using the connection descriptor: Use `(security=(ssl_server_dn_match=yes)(SSL_VERSION=1.3))` in the connection URL

See Also

Oracle Database JDBC Java API Reference for more information

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- Always use the latest update of the JDK

  Use the latest update of JDK 17, JDK 11, or JDK 8 because the updated versions include bug fixes that are required for using TLS version 1.3.

- Use JKS files or Oracle Wallet

> **Note**
>
> Starting from Oracle Database Release 18c, you can specify TLS configuration properties in a new configuration file called `ojdbc.properties`. The use of this file eases the connectivity to Database services on Cloud.

> **See Also**
>
> *Oracle AI Database JDBC Java API Reference*

After performing all the preceding steps, if you run into more issues, then you can turn on tracing to diagnose the problems using `-Djavax.net.debug=all` option.

9.7.5 Automatic TLS Connection Configuration

Starting from Oracle Database Release 18c, you can use default values or programmatic logic for resolving the connection configuration values without manually adding or updating the security provider. You can resolve the configuration values in the following two ways:

- Provider Resolution
- Automatic Key Store Type (KSS) Resolution

9.7.5.1 Provider Resolution

For certain key store types, the JDBC driver resolves the provider implementation that is used to load the key store. For these types, it is not necessary to register the provider with Java security. If the provider implementation is on the `CLASSPATH`, the driver can instantiate the security provider.

The following key store types map to a known provider:

- **SSO:** `oracle.security.pki.OraclePKIProvider`
- **KSS:** `oracle.security.jps.internal.keystore.provider.FarmKeyStoreProvider`

The driver attempts to resolve the provider only if there is no provider registered for the specified type.

If the `oraclepki.jar` file is on the `CLASSPATH`, then the driver can automatically load the Oracle PKI Provider in the following way:

```
java –cp oraclepki.jar:ojdbc11.jar –Djavax.net.ssl.keyStore=/path/to/wallet/
cwallet.sso MyApp
```


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Similarly, for a specified value of the `oracle.net.wallet_location` connection property, the driver can automatically load the Oracle PKI Provider in the following way:

```
java -cp .:oraclepki.jar:ojdbc11.jar -Doracle.net.wallet_location=file:/
path/to/wallet/cwallet.sso MyApp
```

> **Note**
>
> For `PKCS12` types created by the `orapki` tool (The `ewallet.p12` file), you may still need to register the `OraclePKIProvider` with Java security because the `PKCS12` file created by the `orapki` tool includes the ASN1 *Key Bag* element (Type Code: 1.2.840.113549.1.12.10.1.1). The Sun `PKCS12` implementation does not support the *Key Bag* type and throws an error when attempting to read the `ewallet.p12` file. For HotSpot and Open JDK users, the Sun Provider comes bundled as the `PKCS12` provider. This means that the `PKCS12` provider will already have a registered provider, and the driver will make no attempt to override this.

9.7.5.2 Automatic Key Store Type (KSS) Resolution

The JDBC driver can resolve common key store types based on the value of the `javax.net.ssl.keyStore` and `javax.net.ssl.trustStore` properties, eliminating the need to specify the type using these properties.

Key Store or Trust Store with a Recognized File Extension

A key store or trust store with a recognized file extension maps to the following types:

- File extension `.jks` resolves to `javax.net.ssl.keyStoreType` as JKS:

  ```
  java -cp ojdbc11.jar -Djavax.net.ssl.keyStore=/path/to/keystore/
  keystore.jks MyApp
  ```

- File extension `.sso` resolves to `javax.net.ssl.keyStoreType` as SSO:

  ```
  java -cp ojdbc11.jar -Djavax.net.ssl.keyStore=/path/to/keystore/
  keystore.sso MyApp
  ```

- File extension `.p12` resolves to `javax.net.ssl.keyStoreType` as PKCS12:

  ```
  java -cp ojdbc11.jar -Djavax.net.ssl.keyStore=/path/to/keystore/
  keystore.p12 MyApp
  ```

- File extension `.pfx` resolves to `javax.net.ssl.keyStoreType` as PKCS12:

  ```
  java -cp ojdbc11.jar -Djavax.net.ssl.keyStore=/path/to/keystore/
  keystore.pfx MyApp
  ```

Key Store or Trust Store with a URI

If the key store or the trust store is a URI with a `kss://` scheme, this maps to type KSS:

```
java -cp ojdbc11.jar -Djavax.net.ssl.keyStore=kss://MyStripe/MyKeyStore MyApp
```


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> **Note**
>
> You can set the `javax.net.ssl.trustStoreType` and `javax.net.ssl.keyStoreType` properties for overriding the default type resolution.

9.7.6 Support for Default TLS Context

For applications that require finer control over the TLS configuration, you can configure the JDBC driver to use the `SSLContext` returned by the `SSLContext.getDefault` method. Use one of the following methods for the driver to use the default `SSLContext`:

- `javax.net.ssl.keyStore=NONE`
- `javax.net.ssl.trustStore=NONE`

You can use the default `SSLContext` to support key store types that are not file-based. Common examples of such key store types include hardware-based smart cards. Key store types that require programmatic call to the `load(KeyStore.LoadStoreParameter)` method also belong to this category.

> **See Also**
>
> - https://docs.oracle.com/javase/8/docs/api/javax/net/ssl/SSLContext.html#getDefault--
> - https://docs.oracle.com/javase/8/docs/api/java/security/KeyStore.html#load-java.security.KeyStore.LoadStoreParameter-

9.7.6.1 Support for Caching SSLContext Instance

Starting from Oracle Database Release 23ai (23.6.0.0.0), the JDBC Thin driver supports caching SSLContext instances.

When a connection requires an SSLContext for establishing a TLS session with an Oracle Database instance, it queries the SSLContextCache with a SSLConfig instance (key). If an SSLContext exists for an identical SSLConfig, then it is returned to the connection. Otherwise, a new SSLContext is created, cached, and returned to the connection.

The SSLContextCache stores the following information about the SSLContext instances:

- Full path of the files (keystore, truststore, or wallet files) used in the SSLContext creation
- The last modified time of each of the previously-mentioned files
- The last used timestamp of the SSLContext instance
- The name of the providers used for creating the SSLContext instance

Caching of the SSL Context instances provides the following benefits:

- **Transport Layer Security (TLS) Session Resumption Support:** The TLS Session resumption works only if the same SSLContext instance is used for creating various SSL Sessions (SSLEngine). The session cache is maintained with the SSLContext instance.
- **Performance Improvement:** Caching the SSLContext instances improves performance because it avoids reading the truststore and keystore from the file system for each

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connection. Connections with similar TLS configuration can reuse the same SSLContext instance.

The default size of the SSLContextCache is 15. If it reaches its maximum allowed size, then the least recently used entry is removed from the cache before adding a new entry. You can modify the cache size by using the `oracle.net.sslContextCacheSize` system property. Caching is disabled if you set this property to `0` (zero).

See Also

Oracle® Database JDBC Java API Reference

9.7.7 SNI Support for TLS Connections

Starting from Oracle Database Release 23ai (23.7), the JDBC Thin driver supports Server Name Indication (SNI). SNI is a TLS extension that is used to send an unencrypted host name in a `ClientHello` message.

For every TLS connection establishment, you must perform a TLS handshake with both the listener and the foreground database process, which delays the overall connection establishment time.

Using SNI, the client can send the information of the target database service in an unencrypted form in the TLS `ClientHello` message. The listener uses this information to hand-off the request to the foreground database process, without performing the TLS handshake. So, the connection establishment time is reduced due to absence of the TLS handshake with the listener.

You can enable SNI support using one of the following options:

- The `oracle.net.useSNI` connection property. For example:

```
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:oracle:thin:@tcps://mydbhost:3484/mydbservice");
ods.setUser("myusername");
ods.setPassword(<password>);
ods.setConnectionProperty(OracleConnection.CONNECTION_PROPERTY_NET_USE_SNI,
 "true");
Connection conn = ods.getConnection();
conn.close();
```

- The Easy Connect URL. For example:

```
jdbc:oracle:thin:@tcps://mydbhost:3484/myservice?
wallet_location=mywallet&use_sni=true
```

- The connection descriptor. For example:

```
jdbc:oracle:thin:@((DESCRIPTION=(USE_SNI=TRUE)(ADDRESS=(PROTOCOL=TCPS)
(HOST=mydbhost)(PORT=3484))
(CONNECT_DATA=(SERVICE_NAME=myservice))
(SECURITY=(WALLET_LOCATION=mywallet)))
```


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9.7.8 Support for Key Store Service

This release of Oracle Database introduces support for Key Store Service (KSS) in the JDBC driver. So, if you have configured a Key Store Service in a WebLogic server, then JDBC applications can now integrate with the existing Key Store Service configuration.

The driver can load the key stores that are managed by the Key Store Service. If the value of the `javax.net.ssl.keyStore` property or the `javax.net.ssl.trustStore` property is a URI with `kss://` scheme, then the driver loads the key store from Key Store Service.

For permission-based protection, the following permission must be granted to the ojdbc JAR file:

```
permission KeyStoreAccessPermission "stripeName=*,keystoreName=*,alias=*",
"read";
```

This permission grants access to every key store. For limiting the scope of access, you can replace the asterisk wild cards (*) with a specific application stripe and a key store name. The driver does not load the key store as a privileged action, which means that the `KeyStoreAccessPermission` must also be granted to the application code base.

9.8 Support for Kerberos

This section discusses the following topics:

- Overview of JDBC Support for Kerberos
- Configuring Windows to Use Kerberos
- Configuring Oracle Database to Use Kerberos
- Code Example for Using Kerberos
- Support for Kerberos Constrained Delegation
- Kerberos Authentication Enhancements

9.8.1 Overview of JDBC Support for Kerberos

Kerberos is a network authentication protocol that provides the tools of authentication and strong cryptography over the network. Kerberos helps you secure your information systems across your entire enterprise by using secret-key cryptography. The Kerberos protocol uses strong cryptography so that a client or a server can prove its identity to its server or client across an insecure network connection. After a client and server have used Kerberos to prove their identity, they can also encrypt all of their communications to assure privacy and data integrity as they go about their business.

The Kerberos architecture is centered around a trusted authentication service called the key distribution center, or KDC. Users and services in a Kerberos environment are referred to as principals; each principal shares a secret, such as a password, with the KDC. A principal can be a user such as `HR` or a database server instance.

Starting from 12*c* Release 1, Oracle Database supports cross-realm authentication for Kerberos. If you add the referred realm appropriately in the `domain_realms` section of the kerberos configuration file, then being in one particular realm, you can access the services of another realm.

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Starting from Release 19c, Oracle Database supports Kerberos Constrained Delegation. This feature added a new method `OracleConnectionBuilder gssCredential(GSSCredential credential)` in the `oracle.jdbc.OracleConnectionBuilder` interface. This method accepts the GSSCredential of the user and then delegates it during the Kerberos authentication in the driver.

> **See Also**
>
> *Oracle AI Database JDBC Java API Reference*

9.8.2 Configuring Windows to Use Kerberos

A good Kerberos client providing `klist, kinit,` and other tools, can be found at the following link:

`http://web.mit.edu/kerberos/dist/index.html`

This client also provides a nice GUI.

You need to make the following changes to configure Kerberos on your Windows machine:

1. Right-click the **My Computer** icon on your desktop.
2. Select **Properties**. The System Properties dialog box is displayed.
3. Select the **Advanced** tab.
4. Click **Environment Variables**. The Environment Variables dialog box is displayed.
5. Click **New** to add a new user variable. The New User Variable dialog box is displayed.
6. Enter `KRB5CCNAME` in the Variable name field.
7. Enter `FILE:C:\Documents and Settings\<user_name>\krb5cc` in the Variable value field.
8. Click **OK** to close the New User Variable dialog box.
9. Click **OK** to close the Environment Variables dialog box.
10. Click **OK** to close the System Properties dialog box.

> **Note**
>
> `C:\WINDOWS\krb5.ini` file has the same content as `krb5.conf` file.

9.8.3 Configuring Oracle Database to Use Kerberos

Perform the following steps to configure Oracle Database to use Kerberos:

1. Use the following command to connect to the database:

```
SQL> connect system
Enter password: password
```

2. Use the following commands to create a user `CLIENT@MYORACLE.COM` that is identified externally:

```
SQL> create user "CLIENT@MYORACLE.COM" identified externally;
SQL> grant create session to "CLIENT@MYORACLE.COM";
```


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3. Use the following commands to connect to the database as `sysdba` and dismount it:

```
SQL> connect / as sysdba
SQL> shutdown immediate;
```

4. Add the following line to `$T_WORK/t_init1.ora` file:

```
OS_AUTHENT_PREFIX=""
```

5. Use the following command to restart the database:

```
SQL> startup pfile=t_init1.ora
```

6. Modify the `sqlnet.ora` file to include the following lines:

```
names.directory_path = (tnsnames)
#Kerberos
sqlnet.authentication_services = (beq,kerberos5)
sqlnet.authentication_kerberos5_service = dbji
sqlnet.kerberos5_conf = /home/Jdbc/Security/kerberos/krb5.conf
sqlnet.kerberos5_keytab = /home/Jdbc/Security/kerberos/dbji.oracleserver
sqlnet.kerberos5_conf_mit = true
sqlnet.kerberos_cc_name = /tmp/krb5cc_5088
# logging (optional):
trace_level_server=16
trace_directory_server=/scratch/sqlnet/
```

7. Use the following commands to verify that you can connect through SQL*Plus:

```
> kinit client
> klist
     Ticket cache: FILE:/tmp/krb5cc_5088
     Default principal: client@MYORACLE.COM

     Valid starting     Expires            Service principal
     06/22/06 07:13:29  06/22/06 17:13:29  krbtgt/MYORACLE.COM@MYORACLE.COM


     Kerberos 4 ticket cache: /tmp/tkt5088
     klist: You have no tickets cached
> sqlplus '/@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)(HOST=oracleserver.mydomain.com)
(PORT=5221))
(CONNECT_DATA=(SERVICE_NAME=orcl)))'
```

9.8.4 Code Example for Using Kerberos

This following example demonstrates the Kerberos authentication feature that is part of Oracle Database 23ai JDBC thin driver. This demo covers two scenarios:

- In the first scenario, the OS maintains the user name and credentials. The credentials are stored in the cache and the driver retrieves the credentials before trying to authenticate to the server. This scenario is in the module `connectWithDefaultUser()`.

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> **Note**
>
> 1. Before you run this part of the demo, use the following command to verify that you have valid credentials:
>
>    ```
>    > /usr/kerberos/bin/kinit client
>    where, the password is welcome.
>    ```
>
> 2. Use the following command to list your tickets:
>
>    ```
>    > /usr/kerberos/bin/klist
>    ```

- The second scenario covers the case where the application wants to control the user credentials. This is the case of the application server where multiple web users have their own credentials. This scenario is in the module `connectWithSpecificUser()`.

> **Note**
>
> To run this demo, you need to have a working setup, that is, a Kerberos server up and running, and an Oracle database server that is configured to use Kerberos authentication. You then need to change the URLs used in the example to compile and run it.

Example 9-4 Using Kerberos Authentication to Connect to the Database

```
import com.sun.security.auth.module.Krb5LoginModule;
import java.io.IOException;

import java.security.PrivilegedExceptionAction;
import java.sql.Connection;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;

import java.util.HashMap;
import java.util.Properties;
import javax.security.auth.Subject;
import javax.security.auth.callback.Callback;
import javax.security.auth.callback.CallbackHandler;
import javax.security.auth.callback.PasswordCallback;
import javax.security.auth.callback.UnsupportedCallbackException;

import oracle.jdbc.OracleConnection;
import oracle.jdbc.OracleDriver;
import oracle.net.ano.AnoServices;
public class KerberosJdbcDemo
{
  String url ="jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)"+
    "(HOST=oracleserver.mydomain.com)(PORT=5221))(CONNECT_DATA=" +
    "(SERVICE_NAME=orcl)))";

  public static void main(String[] arv)
  {
    /* If you see the following error message [Mechanism level: Could not load
     * configuration file c:\winnt\krb5.ini (The system cannot find the path
     * specified] it's because the JVM cannot locate your kerberos config file.
     * You have to provide the location of the file. For example, on Windows,
     * the MIT Kerberos client uses the config file: C\WINDOWS\krb5.ini:
     */
```


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```
    // System.setProperty("java.security.krb5.conf","C:\\WINDOWS\\krb5.ini");
    System.setProperty("java.security.krb5.conf","/home/Jdbc/Security/kerberos/
krb5.conf");

    KerberosJdbcDemo kerberosDemo = new KerberosJdbcDemo();
    try
    {
      System.out.println("Attempt to connect with the default user:");
      kerberosDemo.connectWithDefaultUser();
    }
    catch (Exception e)
    {
      e.printStackTrace();
    }
    try
    {
      System.out.println("Attempt to connect with a specific user:");
      kerberosDemo.connectWithSpecificUser();
    }
    catch (Exception e)
    {
      e.printStackTrace();
    }
  }


  void connectWithDefaultUser() throws SQLException
  {
    OracleDriver driver = new OracleDriver();
    Properties prop = new Properties();


prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES,
      "("+AnoServices.AUTHENTICATION_KERBEROS5+")");

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_KRB5_MUTUAL
,
      "true");

    /* If you get the following error [Unable to obtain Principal Name for
     * authentication] although you know that you have the right TGT in your
     * credential cache, then it's probably because the JVM can't locate your
     * cache.

     *
     * Note that the default location on windows is "C:\Documents and
Settings\krb5cc_username".
     */

    //
prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_KRB5_CC_NAM
E,

    /*
      On Linux:
         > which kinit
         /usr/kerberos/bin/kinit
         > ls -l /etc/krb5.conf
         lrwxrwxrwx    1 root  root   47 Jun 22 06:56 /etc/krb5.conf -> /home/Jdbc/
Security/kerberos/krb5.conf

         > kinit client
```


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```
          Password for client@MYORACLE.COM:
          > klist
          Ticket cache: FILE:/tmp/krb5cc_5088
          Default principal: client@MYORACLE.COM

          Valid starting     Expires            Service principal
          11/02/06 09:25:11  11/02/06 19:25:11  krbtgt/MYORACLE.COM@MYORACLE.COM


          Kerberos 4 ticket cache: /tmp/tkt5088
          klist: You have no tickets cached
    */

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_KRB5_CC_NAM
E,
                     "/tmp/krb5cc_5088");
    Connection conn  = driver.connect(url,prop);
    String auth = ((OracleConnection)conn).getAuthenticationAdaptorName();
    System.out.println("Authentication adaptor="+auth);
    printUserName(conn);
    conn.close();
  }


  void connectWithSpecificUser() throws Exception
  {
    Subject specificSubject = new Subject();

    // This first part isn't really meaningful to the sake of this demo. In
    // a real world scenario, you have a valid "specificSubject" Subject that
    // represents a web user that has valid Kerberos credentials.
    Krb5LoginModule krb5Module = new Krb5LoginModule();
    HashMap sharedState = new HashMap();
    HashMap options = new HashMap();
    options.put("doNotPrompt","false");
    options.put("useTicketCache","false");
    options.put("principal","client@MYORACLE.COM");

    krb5Module.initialize(specificSubject,newKrbCallbackHandler(),sharedState,options);
    boolean retLogin = krb5Module.login();
    krb5Module.commit();
    if(!retLogin)
      throw new Exception("Kerberos5 adaptor couldn't retrieve credentials (TGT) from
the cache");

    // to use the TGT from the cache:
    // options.put("useTicketCache","true");
    // options.put("doNotPrompt","true");
    // options.put("ticketCache","C:\\Documents and Settings\\user\\krb5cc");
    // krb5Module.initialize(specificSubject,null,sharedState,options);


    // Now we have a valid Subject with Kerberos credentials. The second scenario
    // really starts here:
    // execute driver.connect(...) on behalf of the Subject 'specificSubject':
    Connection conn =
      (Connection)Subject.doAs(specificSubject, new PrivilegedExceptionAction()
        {
          public Object run()
          {
            Connection con = null;
            Properties prop = new Properties();
```


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```
            prop.setProperty(AnoServices.AUTHENTICATION_PROPERTY_SERVICES,
                             "(" + AnoServices.AUTHENTICATION_KERBEROS5 + ")");
            try
            {
              OracleDriver driver = new OracleDriver();
              con = driver.connect(url, prop);

            } catch (Exception except)
            {
              except.printStackTrace();
            }
            return con;
          }
        });

    String auth = ((OracleConnection)conn).getAuthenticationAdaptorName();
    System.out.println("Authentication adaptor="+auth);
    printUserName(conn);
    conn.close();
  }

  void printUserName(Connection conn) throws SQLException
  {
    Statement stmt = null;
    try
    {
      stmt = conn.createStatement();
      ResultSet rs = stmt.executeQuery("select user from dual");
      while(rs.next())
        System.out.println("User is:"+rs.getString(1));
      rs.close();
    }
    finally
    {
      if(stmt != null)
        stmt.close();
    }
  }
}

class KrbCallbackHandler implements CallbackHandler
{
 public void handle(Callback[] callbacks) throws IOException,
                                                 UnsupportedCallbackException
 {
   for (int i = 0; i < callbacks.length; i++)
   {
     if (callbacks[i] instanceof PasswordCallback)
     {
       PasswordCallback pc = (PasswordCallback)callbacks[i];
       System.out.println("set password to 'welcome'");
       pc.setPassword((new String("welcome")).toCharArray());
     } else
     {
       throw new UnsupportedCallbackException(callbacks[i],
                                              "Unrecognized Callback");
     }
   }
 }
}
```


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9.8.5 Support for Kerberos Constrained Delegation

Starting from Oracle Database Release 19c, the Thin driver supports the Kerberos constrained delegation feature.

To make it a secure practice, the implementation relies on the use of the `GSSCredential` utility. For this purpose, the `OracleConnectionBuilder` interface has been enhanced, so that it can accept a `GSSCredential` object.

Example 9-5 Using Constrained Delegation

The following example shows how to implement constrained delegation in your code:

```
OracleDataSource ods = new OracleDataSource();
ods.setURL(url);
ods.setConnectionProperties(prop);
con = ods.createConnectionBuilder()
                 .gssCredential(impersonatedGssUserCreds)
                .build();
```

See Also

- Java Platform, Standard Edition Security Developer's Guide
- The OracleConnectionBuilder Interface

9.8.6 Kerberos Authentication Enhancements

Starting with Oracle Database Release 23ai, Kerberos authentication does not need instantiating the `KerberosLoginModule` or the availability of Ticket Granting Ticket (TGT) in the `CredentialCache`.

In this release, you can connect to Oracle Database using the following enhanced Kerberos Authentication methods:

- Kerberos Authentication Using the User and the Password Properties
- Kerberos Authentication Using the JAAS Configuration

9.8.6.1 Kerberos Authentication Using the User and the Password Properties

Now you can configure the Kerberos Principal and Password properties in the same way as you configure the user and password properties for a simple authentication (`O5Logon`). Using these values, the JDBC Thin driver initializes the `KerberosLoginModule` for your application, simplifying the Kerberos Authentication configuration.

For using the configured user name and password, you must set the `PASSWORD_AUTH` parameter to `KERBEROS5` in the connection string. You can also set `PASSWORD_AUTH` to `KERBEROS5` using the `oracle.jdbc.passwordAuthentication` connection property. However, the value specified in the connection string has a higher priority.

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Example 9-6 Kerberos Authentication: Using the User and the Password Properties

The following example shows how you can configure the Kerberos Principal and the Password:

```
import oracle.jdbc.OracleConnection;
import oracle.jdbc.OracleDriver;
import java.sql.Connection;
import java.sql.SQLException;
import java.util.Properties;

public class KerberosExample {

  private static String KERBEROS_PRINCIPAL = "client@EXAMPLE.COM";
  private static String PASSWORD = <password>;
  private static String URL
="jdbc:oracle:thin:@(DESCRIPTION=(SECURITY=(PASSWORD_AUTH=KERBEROS5))
(ADDRESS=(PROTOCOL=TCP)"+
      "(HOST=myserver.example.com)(PORT=5221))
(CONNECT_DATA=(SERVICE_NAME=orcl)))";

  public static void main(String a[]) {
    try{
      Properties prop = new Properties();
      prop.setProperty("oracle.net.authentication_services", "(KERBEROS5)");
      prop.setProperty("user", KERBEROS_PRINCIPAL); // Kerberos Principal
      prop.setProperty("password", PASSWORD); // Kerberos Password
      OracleDriver driver = new OracleDriver();
      Connection conn  = driver.connect(URL, prop);
      String auth = ((OracleConnection)conn).getAuthenticationAdaptorName();
      System.out.println ("Authentication adaptor=" + auth);
      conn.close();
    }
    catch(SQLException e) {
      e.printStackTrace();
    }
  }

}
```

9.8.6.2 Kerberos Authentication Using the JAAS Configuration

In this release, you can specify the JAAS configuration file through the JDBC connection properties. By default, the Thin driver uses the default kerberos login module that is bundled with Oracle JDK (`com.sun.security.auth.module.Krb5LoginModule`). If you want to override this behaviour in your application, then use the JAAS configurations.

The following code example shows how you can configure the Kerberos Authentication using the JAAS configurations:

```
import java.sql.Connection;
import java.util.Properties;

import oracle.jdbc.OracleDriver;
import oracle.jdbc.OracleConnection;

public class JAASKerberosAuthentication {
```


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```
  // Set the following properties
  private final static String DB_URL = "jdbc:oracle:thin:@(DESCRIPTION=" +
      "(ADDRESS=(PROTOCOL=TCP)(HOST=myserver.example.com)(PORT=5221))" +
      "(CONNECT_DATA=(SERVICE_NAME=orcl)))";
  private final static String KERBEROS_CONFIG_FILE = "/etc/krb5.conf";
  private final static String JAAS_CONFIG_FILE_PATH = "/myworkdir/jaas.conf";
  private final static String KERBEROS_LOGIN_MODULE_NAME = "kprb5module";

  public static void main(String a[]) throws Exception {
    // Set JAAS configuration

System.setProperty("java.security.auth.login.config",JAAS_CONFIG_FILE_PATH);

    // Set Kerberos Configuration
    System.setProperty("java.security.krb5.conf", KERBEROS_CONFIG_FILE);

    OracleDriver driver = new OracleDriver();
    Properties prop = new Properties();
    prop.setProperty("oracle.net.authentication_services", "(KERBEROS5)");
    prop.setProperty("oracle.net.KerberosJaasLoginModule",
KERBEROS_LOGIN_MODULE_NAME);
    Connection conn = driver.connect(DB_URL, prop);
    String auth = ((OracleConnection) conn).getAuthenticationAdaptorName();
    System.out.println("Got Connection. Authentication adaptor=" + auth);
    conn.close();
  }
}
```

The preceding example uses the following JAAS configuration file in the `/myworkdir/jaas.conf` directory:

```
kprb5module {
     com.sun.security.auth.module.Krb5LoginModule required
                doNotPrompt=true useTicketCache=true ticketCache="file:/tmp/
krb5cc_5088";
};
```

9.9 Support for RADIUS

This section describes the following concepts:

- Overview of JDBC Support for RADIUS
- Configuring Oracle Database to Use RADIUS
- Code Example for Using RADIUS
- Support for Challenge-Response Authentication

9.9.1 Overview of JDBC Support for RADIUS

Oracle Database 11*g* Release 1 introduced support for Remote Authentication Dial-In User Service (RADIUS). RADIUS is a client/server security protocol that is most widely known for enabling remote authentication and access. Oracle Advanced Security uses this standard in a

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client/server network environment to enable use of any authentication method that supports the RADIUS protocol. RADIUS can be used with a variety of authentication mechanisms, including token cards and smart cards.

9.9.2 Configuring Oracle Database to Use RADIUS

Perform the following steps to configure Oracle Database to use RADIUS:

1. Use the following command to connect to the database:

```
SQL> connect system
Enter password: password
```

2. Use the following commands to create a new user `aso` from within a database:

```
SQL> create user aso identified externally;
SQL> grant create session to aso;
```

3. Use the following commands to connect to the database as `sysdba` and dismount it:

```
SQL> connect / as sysdba
SQL> shutdown immediate;
```

4. Add the following lines to the `t_init1.ora` file:

```
os_authent_prefix = ""
```

> **Note**
>
> Once the test is over, you need to revert the preceding changes made to the t_init1.ora file.

5. Use the following command to restart the database:

```
SQL> startup pfile=?/work/t_init1.ora
```

6. Modify the `sqlnet.ora` file so that it contains only these lines:

```
sqlnet.authentication_services = ( beq, radius)
sqlnet.radius_authentication = <RADUIUS_SERVER_HOST_NAME>
sqlnet.radius_authentication_port = 1812
sqlnet.radius_authentication_timeout = 120
sqlnet.radius_secret=/home/Jdbc/Security/radius/radius_key
# logging (optional):
trace_level_server=16
trace_directory_server=/scratch/sqlnet/
```

7. Use the following command to verify that you can connect through SQL*Plus:

```
>sqlplus 'aso/1234@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
(HOST=oracleserver.mydomain.com)(PORT=5221))
(CONNECT_DATA=(SERVICE_NAME=orcl)))'
```

9.9.3 Code Example for Using RADIUS

This example demonstrates the RADIUS authentication feature that is a part of Oracle Database 23ai JDBC thin driver.

You need to have a working setup, that is, a RADIUS server up and running, and an Oracle database server that is configured to use RADIUS authentication. You then need to change the URLs given in the example to compile and run it.

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Example 9-7 Using RADIUS Authentication to Connect to the Database

```
import java.sql.Connection;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;
import java.util.Properties;
import oracle.jdbc.OracleConnection;
import oracle.jdbc.OracleDriver;
import oracle.net.ano.AnoServices;
public class RadiusJdbcDemo
{
  String url ="jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)"+
    "(HOST=oracleserver.mydomain.com)(PORT=5221))(CONNECT_DATA=" +
    "(SERVICE_NAME=orcl)))";

  public static void main(String[] arv)
  {
    RadiusJdbcDemo radiusDemo = new RadiusJdbcDemo();
    try
    {
      radiusDemo.connect();
    }
    catch (Exception e)
    {
      e.printStackTrace();
    }
  }

  /*
   * This method attempts to logon to the database using the RADIUS
   * authentication protocol.
   *
   * It should print the following output to stdout:
   * -----------------------------------------------------
   * Authentication adaptor=RADIUS
   * User is:ASO
   * -----------------------------------------------------
   */
  void connect() throws SQLException
  {
    OracleDriver driver = new OracleDriver();
    Properties prop = new Properties();


prop.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_AUTHENTICATION_SERVICES,
      "("+AnoServices.AUTHENTICATION_RADIUS+")");
    // The user "aso" needs to be properly setup on the radius server with
    // password "1234".
    prop.setProperty("user","aso");
    prop.setProperty("password","1234");

    Connection conn  = driver.connect(url,prop);
    String auth = ((OracleConnection)conn).getAuthenticationAdaptorName();
    System.out.println("Authentication adaptor="+auth);
    printUserName(conn);
    conn.close();
  }


  void printUserName(Connection conn) throws SQLException
  {
```


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```
    Statement stmt = null;
    try
    {
      stmt = conn.createStatement();
      ResultSet rs = stmt.executeQuery("select user from dual");
      while(rs.next())
        System.out.println("User is:"+rs.getString(1));
      rs.close();
    }
    finally
    {
      if(stmt != null)
        stmt.close();
    }
  }
}
```

9.9.4 Support for Challenge-Response Authentication

The RADIUS challenge-response authentication is an interactive authentication, where the RADIUS server asks for a valid response to a displayed challenge. Starting from Oracle Database Release 23ai, the JDBC thin drivers support this authentication.

In challenge-response authentication, the first level of authentication is performed using the user name and the password. The RADIUS server then sends a challenge to the application, to which the application must respond. For handling the challenge, you must configure a handler in your application, which is responsible for producing the response, using a given hint. The hint is provided to the handler as a byte array and the value of the byte array is dependent on the configuration of the challenge-response authentication in the RADIUS server.

> **See Also**
>
> Oracle Database Security Guide

You can configure the handler in the following two ways:

- Using the `oracle.net.radius_challenge_response_handler` connection property
- Using the `ConnectionBuilder.radiusChallengeResponseHandler` method

Using the oracle.net.radius_challenge_response_handler Connection Property

Use the `oracle.net.radius_challenge_response_handler` connection property to configure the fully qualified name of the class that handles the challenge. This handler class must implement the `java.util.function.Function<byte[], byte[]>` interface. The following example shows how to configure RADIUS challenge-response authentication using the `oracle.net.radius_challenge_response_handler` connection property.

```
import oracle.jdbc.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;

import java.sql.SQLException;
import java.util.Properties;
import java.util.function.Function;

public class RadiusExample {
```


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```
  private static String USER = "myRadiusUser";
  private static String PASSWORD = "myRadiusPwd";
  private static String URL
="jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)"+
      "(HOST=myserver.example.com)(PORT=5221))
(CONNECT_DATA=(SERVICE_NAME=orcl)))";

  public static void main(String a[]) {
    try {
      OracleDataSource ods  = new OracleDataSource();
      Properties prop = new Properties();
      prop.setProperty("oracle.net.authentication_services", "RADIUS");
      prop.setProperty("user", USER);
      prop.setProperty("password", PASSWORD);
      prop.setProperty("oracle.net.radius_challenge_response_handler",
"MyChallengeResponseHandler");
      ods.setConnectionProperties(prop);
      ods.setURL(URL);
      OracleConnection conn = (OracleConnection) ods.getConnection();
      System.out.println("Got Connection. Authentication adaptor="+
conn.getAuthenticationAdaptorName());
      conn.close();
    }
    catch(SQLException e) {
      e.printStackTrace();
    }

  }

  class MyChallengeResponseHandler implements Function<byte[], byte[]> {
    @Override
    public byte[] apply(byte[] hint) {
      // TODO: use the hint to produce the challenge response
      byte[] response = null;
      return response;
    }
  }

}
```

Using the ConnectionBuilder.radiusChallengeResponseHandler Method

You can configure the handler using the new `ConnectionBuilder.radiusChallengeResponseHandler` method. Use this method to specify the handler lambda / instance. The following example shows how to configure RADIUS challenge-response authentication using the `radiusChallengeResponseHandler` method:

```
import oracle.jdbc.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;

import java.sql.SQLException;
import java.util.Properties;

public class RadiusExample {

  private static String USER = "myRadiusUser";
```


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```
  private static String PASSWORD = "myRadiusPwd";
  private static String URL
="jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)"+
      "(HOST=myserver.example.com)(PORT=5221))
(CONNECT_DATA=(SERVICE_NAME=orcl)))";

  public static void main(String a[]) {
    try {
      OracleDataSource ods  = new OracleDataSource();
      Properties prop = new Properties();
      prop.setProperty("oracle.net.authentication_services", "RADIUS");
      prop.setProperty("user", USER);
      prop.setProperty("password", PASSWORD);
      ods.setConnectionProperties(prop);
      ods.setURL(URL);
      OracleConnection conn  = ods.createConnectionBuilder()
          .radiusChallengeResponseHandler(RadiusExample::getResponse).build();
      System.out.println("Got Connection. Authentication adaptor="+
conn.getAuthenticationAdaptorName());
      conn.close();
    }
    catch(SQLException e) {
      e.printStackTrace();
    }
  }

  private static byte[] getResponse(byte[] hint) {
    // TODO: use the hint to produce the challenge response
    byte[] response = null;
    return response;
  }

}
```

9.10 Support for FIPS with Native Network Encryption

Starting with Oracle Database Release 19c, the JDBC Thin drivers support the Federal Information Processing Standards (FIPS).

For enabling FIPS support, you should use `CONNECTION_PROPERTY_THIN_NET_SET_FIPS_MODE`. By default, this property is set to `false`. You must set it to `true`, to enable FIPS mode for native network encryption.

> **Note**
>
> FIPS with TLS connection does not require this configuration.

> **See Also**
>
> Oracle Database JDBC Java API Reference

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Example 9-8 Enabling FIPS Mode in Your Application

The following example demonstrates how you can enable FIPS mode in your application:

```
import java.sql.*;
import java.util.*;

import oracle.jdbc.*;

import java.security.*;

import org.bouncycastle.jcajce.provider.BouncyCastleFipsProvider;

public class TestFIPS {
  static String driver = "thin";
  static String protocol = "tcp";
  static String user = "scott";
  static String password = "<password>";
  static String url = "jdbc:oracle:" + driver +
":@(DESCRIPTION=(ADDRESS=(PROTOCOL=" + protocol + ")(HOST=" +
System.getenv("HOST") + ")(PORT=3484))
(CONNECT_DATA=(SERVICE_NAME=myservice.com))
(SECURITY=(ENCRYPTION_CLIENT=REQUESTED)))";

  public static void main(String[] args) throws Exception {

    System.setProperty("org.bouncycastle.fips.approved_only", "true");
    Provider bcFipsProvider = new BouncyCastleFipsProvider();
    Security.insertProviderAt(bcFipsProvider, 1);

    Properties props = new Properties();
    props.setProperty("user", user);
    props.setProperty("password", password);

props.setProperty(OracleConnection.CONNECTION_PROPERTY_THIN_NET_SET_FIPS_MODE,
 "true");
    show("DEBUG: Properties: " + props);

    try (Connection conn = DriverManager.getConnection(url, props);) {
      checkConn(conn);
    } catch (Exception e) {
      e.printStackTrace();
    }
  }

  public static void checkConn(Connection conn) throws Exception {
    String sql = "select user from dual";
    try (Statement st = conn.createStatement();
         ResultSet rs = st.executeQuery(sql);){
      String user = "";
      while (rs.next()) {
        user = rs.getString(1);
      }
      show("Connect with user : " + user);
      String EncryptionAlgorithmName = ((OracleConnection)
conn).getEncryptionAlgorithmName();
```


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```
      show("Connection EncryptionAlgorithmName : " + EncryptionAlgorithmName);
    } catch (Exception e) {
      e.printStackTrace();
    }
  }

  private static void show(String msg) {
    System.out.println(msg);
  }

  private static void doSQL(Connection conn, String sql) throws SQLException {
    try (Statement stm = conn.createStatement()){
      stm.execute(sql);
    }
  }
}
```

9.11 Support for PEM in JDBC

Starting with Oracle Database Release 23ai, version 23.6, the JDBC thin driver supports PEM (Privacy Enhanced Mail) files, which can be used to store and transmit public key and certificate information.

You can use the `oracle.net.wallet_location` JDBC property to configure the JDBC driver with a PEM file. If the PEM file uses a password, then use the `oracle.net.wallet_password` property as well. The following are a few examples that show how to configure the driver:

```
oracle.net.wallet_location=file:/<path>/ewallet.pem
oracle.net.wallet_location=(SOURCE=(METHOD=FILE)(METHOD_DATA=(DIRECTORY=/
<path_to_directory>)))
oracle.net.wallet_location="data:; base64,<Base64_representation_of_the_bytes_i
n_ewallet.pem>"
```

Set the PEM file location in the connection string in either of the following ways:

- Using the TNS connection string:

  ```
  jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcps)(HOST=host)
  (PORT=5521))(CONNECT_DATA=
  (SERVICE_NAME=<service_name>))(SECURITY=(WALLET_LOCATION=/<mywallets>/
  ewallet.pem)))
  ```

- Using the EasyConnect URL:

  ```
  jdbc:oracle:thin:@tcps://host:port/<service_name>?wallet_location=/
  mywallets/ewallet.pem
  ```

  or

  ```
  jdbc:oracle:thin:@tcps://host:port/servicename?wallet_location=/mywallets/
  ```


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9.11.1 Centralized PEM File Configuration

This section lists code snippets to describe how to centrally configure a PEM file, using unencrypted and encrypted PEM files.

With Unencrypted PEM Files

You can store the unencrypted PEM file, without making any modification to it, in a vault secret and configure the driver with the following JSON file:

```
{
  "connect_descriptor": "...",
  "user": "scott",
  "password": {
    "type": "ocivault",
    "value": "ocid1.vaultsecret.oc1.phx.amaaaaaxxxx",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
    }
  },

  "wallet_location": {
    "type": "ocivault",
    "value": "ocid1.vaultsecret.oc1.phx.amaaaaY",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
    }
  },
  "jdbc": {
    "oracle.jdbc.ReadTimeout": 1000,
    "defaultRowPrefetch": 20,
    "autoCommit": "false"
}}
```

With Encrypted PEM Files

You can store the encrypted PEM file, without making any modification to it, in a vault secret and configure the driver with the following JSN file:

```
{
  "connect_descriptor": "...",
  "user": "scott",
  "password": {
    "type": "ocivault",
    "value": "ocid1.vaultsecret.oc1.phx.amaaaaaxxxx",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
    }
  },
  "wallet_location": {
    "type": "ocivault",
    "value": "ocid1.vaultsecret.oc1.phx.amaaaaY",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
```


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```
    }
  },
  "wallet_password": {
    "type": "ocivault",
    "value": "ocid1.vaultsecret.oc1.phx.amabbbbaxxxx",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
    }
  },
  "jdbc": {
    "oracle.jdbc.ReadTimeout": 1000,
    "defaultRowPrefetch": 20,
    "autoCommit": "false"
}}
```

9.12 Support for Secure External Password Store (SEPS)

For large-scale deployments where applications use password credentials to connect to databases, you can use a client-side Oracle wallet to store such credentials. An Oracle wallet is a secure software container that is used to store authentication and sign-in credentials.

Storing database password credentials in a client-side Oracle wallet eliminates the need to embed user names and passwords in application code, batch jobs, or scripts. This reduces the risk of exposing passwords in the scripts and application code, and simplifies maintenance because you do not need to change your code each time user names and passwords change. In addition, if you do not have to change the application code, then it also becomes easier to enforce password management policies for these user accounts.

You can store the credentials in the following ways:

- Using the connection descriptor:

  ```
  mkstore -wrl ./client_wallet -createCredential \(DESCRIPTION=\(ADDRESS=\
  (PROTOCOL=tcp\)
  \(HOST=<servername>\)\(PORT=5560\)\)\(CONNECT_DATA=\
  (SERVICE_NAME=<service_name>\)\)\) <user_name> <password>
  ```

  Where, the JDBC URL is in the following format:

  ```
  jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS(PROTOCOL=tcp)(HOST=<servername>)
  (PORT=5560))(CONNECT_DATA=(SERVICE_NAME=<service_name>)))
  ```

- Using the default keys:

  ```
  mkstore -wrl .\walletpath -createEntry
  oracle.security.client.default_username <user_name>
  mkstore -wrl .\walletpath -createEntry
  oracle.security.client.default_password <password>
  ```

- Using the `orapki` command-line interface:

  ```
  $ orapki secretstore create_entry -wallet <wallet> -pwd <password> -
  default -alias oracle.security.client.default_username -secret <username>
  ```


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```
$ orapki secretstore create_entry -wallet <wallet> -pwd <password> -
default -alias oracle.security.client.default_password -secret <password>
```

You can set the `oracle.net.wallet_location` connection property to specify the wallet location. The JDBC driver can then retrieve the user name and password pair from this wallet.

> **Note**
>
> When an Oracle wallet is opened in a JDBC application, for security reasons, the wallet file permissions are aligned to make it accessible only to the wallet owner (creator).

> **See Also**
>
> - Oracle Database JDBC Java API Reference for more information about managing the secure external password store
> - *Oracle Database Administrator's Guide* for more information about configuring your client to use secure external password store and for information about managing credentials in it

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10

JDBC Service Provider Extensions

Starting with Oracle Database Release 23ai, you can extend the capabilities of Oracle JDBC drivers through service providers. You can use the standard Service Provider Interface to define custom providers and load them at run time.

You can load the following three types of providers:

- Centralized Configuration Providers
- Resource Providers
- Trace Event Listener Providers
- JDBC Extensions for Cloud Vendors

The following diagram illustrates the use cases for each provider:

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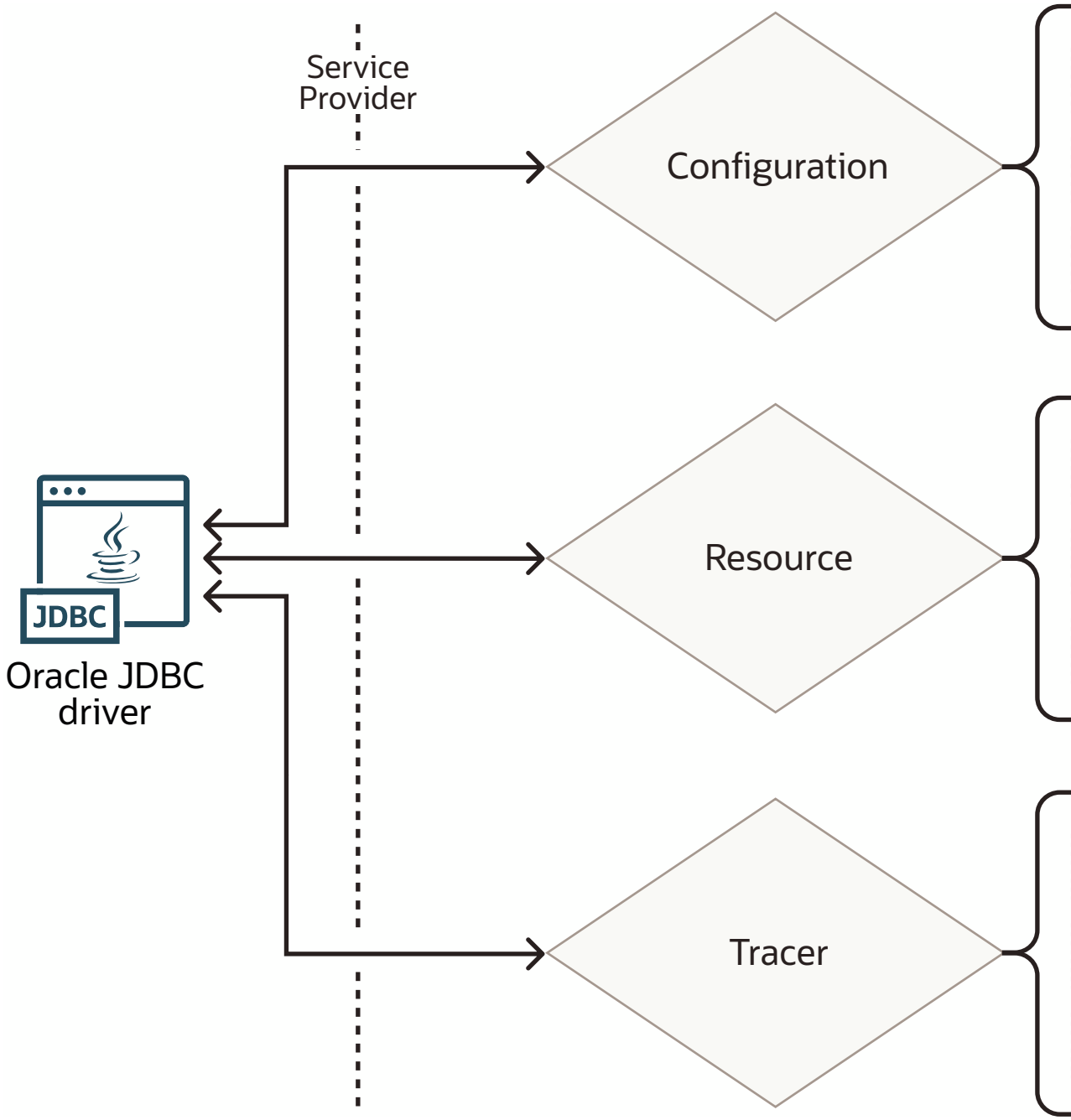

Oracle provides Open Source Providers for the following:

- Azure App Configuration
- OCI Object Storage
- Azure Vault
- Azure Active Directory Token
- OCI IAM Token
- OCI Vault
- Open Telemetry

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- OCI APM
- HashiCorp Vault (through partnership)

10.1 Centralized Configuration Providers

Use these providers to support distributed configurations of database clients.

> **Note**
>
> You can find the specification for the payloads and formats across .NET and C++ clients.

A Centralized Configuration Provider furnishes the Oracle JDBC drivers with the necessary information for creating a database connection including a connection string (JDBC URL), and optionally, JDBC connection properties such as user ID, database password, or wallet location. Sensitive information such as the Database password or wallet location is typically stored separately in a vault.

The Service Provider contract is defined in such a way that if the JDBC URL is of the following format:

```
jdbc:oracle:<driver type>:@config-<provider>
```

then, the driver attempts to load the <*provider*> from the list of registered service providers. For example:

```
jdbc:oracle:thin:@config-azure:myappconfig?key=sales_app1&label=dev
```

To make the external provider discoverable to the applications, you must take care of the following:

- Implement the `oracle.jdbc.spi.OracleConfigurationProvider` interface available in the JDBC Driver
- Provide the URL string of the `<provider>` by overriding the `getType` method
- Provide an implementation of the `getConnectionProperties` method to return the properties to be used by the JDBC Driver

Oracle distributes individual JAR files as Configuration Providers for the following services in the Maven Central repository:

- Azure App Configuration (with optional reference to Azure Key Vault for secrets)
- OCI Object Storage (with optional reference to OCI Vault for secrets)
- OCI Database Tools Connections (with optional reference to OCI Vault for secrets)

If you want to build your own providers, then you must extend the `oracle.jdbc.spi.OracleConfigurationProvider` interface and follow the Java SPI specification.

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10.1.1 Azure App Configuration

The Oracle data source uses a new prefix `jdbc:oracle:thin:@config-azure:` to be able to identify the configuration parameters that should be loaded to use the Azure App Configuration.

For enabling the existing applications to use this feature transparently, you only need to specify the name of the Azure App Configuration, and optionally, a prefix for the key-names and the Label, with the following syntax:

```
jdbc:oracle:thin:@config-azure:{appconfig-name}[?
key=prefix&label=value&option1
=value1&option2=value2]
```

The only requirements are the following:

- Include the provider JAR file in the classpath or the provider reference in the POM file
- Replace the existing URL values with the required values

This feature attaches the values of a data source to a key, which is the prefix of multiple keys in the Azure App Configuration, and a label. Both the key and the label are optional. If those are not specified, then it attaches all the values with no labels and no prefixes in the configuration.

Following are the four fixed values that are looked at with this key and label pair:

- `connect_descriptor` (required)
- `user` (optional)
- `password` (optional)
- `wallet_location` (optional)

The rest of the values are dependent on the JDBC Driver, which have the `jdbc/` prefix. Multiple key-values pairs are retrieved for a specific label and key, which are applied to a data source. The key values are the properties (constant keys) defined in the `OracleConnection` interface.

For example, a data source URL with the value `jdbc:oracle:thin:@config-azure:myappconfig?key=/sales_app1/&label=dev` in an App Configuration, say `myappconfig`, generates an `OracleDatasource` with values similar to the following values:

> **Note**
>
> - Keep in mind that the prefix is `/sales_app1/` and the label is `dev`.
> - The JDBC Driver internally concatenates the connection descriptor with `jdbc:oracle:thin:@` to set the URL. This enables sharing the property with the other driver implementations.

Key	Value	Label	JDBC Driver Connection Property
`/sales_app1/user`	`scott`	dev	`user=scott`

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Key	Value	Label	JDBC Driver Connection Property
/sales_app1/password	{"uri":"https://mykeyvault.vault.azure.net/secrets/<*password*>"}	dev	password=<*password*> (Value of the secret in the URI)
/sales_app1/wallet_location	{"uri":"https://mykeyvault.vault.azure.net/secrets/<*wallet_location*>"}	dev	oracle.net.wallet_location (value: "data:; base64,<value of the secret in the URI>")
/sales_app1/connect_descriptor	(description=(retry_count=20)(retry_delay=3s)(address=(protocol=tcps)(port=1521)(host=myserver.oraclecloud.com))(connect_data=(service_name=myservice.oraclecloud.com))(security=(ssl_server_dn_match=yes)(ssl_server_cert_dn="CN=DN1.oraclecloud.com, OU=Oracle US, O=Oracle Corporation, L=Redwood City, ST=California, C=US")))	dev	URL=jdbc:oracle:thin:@(description=(retry_count=20)(retry_delay=3s)(address=(protocol=tcps)(port=1521)(host=myserver.oraclecloud.com))(connect_data=(service_name=myservice.oraclecloud.com))(security=(ssl_server_dn_match=yes)(ssl_server_cert_dn="CN=DN1.oraclecloud.com, OU=Oracle US, O=Oracle Corporation, L=Redwood City, ST=California, C=US")))
/sales_app1/jdbc/autoCommit	false	dev	autoCommit=false
/sales_app1/jdbc/oracle.jdbc.loginTimeout	20	dev	oracle.jdbc.loginTimeout=20
/sales_app1/jdbc/oracle.jdbc.fanEnabled	false	dev	oracle.jdbc.fanEnabled=false

The following code snippet shows the relevant details in a sample Java client:

```
OracleDataSource ds = new OracleDataSource();
ds.setURL("jdbc:oracle:thin:@config-azure:myappconfig?
key=sales_app1&label=dev");
Connection cn = ds.getConnection();
Statement st = cn.createStatement();
ResultSet rs = st.executeQuery("select sysdate from dual");
```


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10.1.2 OCI Object Storage

For using this Configuration Provider, you must make optional references to OCI Vault for secrets.

In this case, the configuration is stored in JSON format, which is common to all the clients. The provider is identified by `ociobject` provider in the URL, as shown in the following example:

```
jdbc:oracle:thin:@config-ociobject:
https://objectstorage.oraclecloud.com/myjava/bucket1/
payload_ojdbc_objectstorage.json
```

The only required parameter is the URL Path (URI) of the object. You can retrieve this value from the OCI Web Console, using the following navigation: `Object Storage / Buckets / Object → Object Details`, which retrieves a value similar to the following:

```
https://objectstorage.oraclecloud.com/myjava/bucket1/
payload_ojdbc_objectstorage.json
```

There are four fixed values that are looked with this `prefix` and `label` pair:

- `connect_descriptor` (required)
- `user` (optional)
- `password` (optional)
- `wallet_location` (optional)

The rest of the values are dependent on the JDBC Driver, which have the `jdbc/` prefix. Multiple key-values pairs are retrieved for a specific label and key, which are applied to a data source. The key values are the properties (constant keys) defined in the `OracleConnection` interface.

The `password` and `wallet_location` are references to a Vault provider, as shown in the following code snippet:

> **Note**
>
> The Vault provider can also be an Azure Key Vault, which uses `vault-azure` as its type.

```
{"connect_descriptor": "(description=(retry_count=20)(retry_delay=3s)
(address=(protocol=tcps)(port=1521)(host=myhost.oraclecloud.com))
(connect_data=(service_name=myservice.oraclecloud.com))
(security=(ssl_server_dn_match=yes)))",
  "user": "scott",
  "password": {
    "type": "vault-oci",
    "value": "myvalue",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
    }
  },
```


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```
  "wallet_location": {
    "type": "vault-oci",
    "value": "myvalue",
    "authentication": {
      "method": "OCI_INSTANCE_PRINCIPAL"
    }
  },
  "jdbc": {
    "oracle.jdbc.ReadTimeout": 1000,
    "defaultRowPrefetch": 20,
    "autoCommit": "false"
}}
```

You can set multiple keys in one payload, adding the optional name in the URL. For example:

```
jdbc:oracle:thin:@config-ociobject:{object-url}
[?key=name&option1=value1&option2=value2]
```

The following example uses two keys, namely, `sales_app1` and `hr_internal_app1`:

```
{
  "sales_app1":
  {"connect_descriptor": "(description=(address=(protocol=tcps)
(port=1521)(host=myhost.oraclecloud.com))
    (connect_data=(service_name=myservice.oraclecloud.com))
(security=(ssl_server_dn_match=yes)))",
    "user": "scott",
    "password": {
      "type": "vault-oci",
      "value": "myvalue",
      "authentication": {
        "method": "OCI_INSTANCE_PRINCIPAL"
      }
    },
    "jdbc": {
      "oracle.jdbc.ReadTimeout": 1000,
      "defaultRowPrefetch": 20,
      "autoCommit": "false"
    }
  },
  "hr_internal_app1":
  {"connect_descriptor": "(description=(address=(protocol=tcps)
(port=1521)(host=myhost.oraclecloud.com))
    (connect_data=(service_name=myservice.oraclecloud.com))
(security=(ssl_server_dn_match=yes)))",
    "user": "scott",
    "password": {
      "type": "vault-oci",
      "value": "myvalue",
      "authentication": {
        "method": "OCI_INSTANCE_PRINCIPAL"
      }
    },
```


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```
    "jdbc": {
     "oracle.jdbc.ReadTimeout": 0,
     "defaultRowPrefetch": 100,
     "autoCommit": "true"
    }
  }
}
```

10.1.3 OCI Database Tools

For using this Configuration Provider, you must make optional reference to OCI Vault for secrets.

The OCI Database Tools service is a managed service that can be used to configure connections to a database, either Oracle Autonomous Database or MySQL. You can then use the `connection` objects in the SQL worksheet in the Web console. You can also use it as a directory of database connection configurations, and also as a provider that allows access to these configurations. Each configuration has an Oracle Cloud Identifier (OCID) that is used to identify which connection is used. It contains a `connectionString`, a `userName`, a `userPassword`, `keyStores`, and `advancedProperties`. The `advancedProperties` are currently limited to JDBC properties.

The example shows a JDBC URL that uses the OCI Database Tools provider:

```
jdbc:oracle:thin:@config-ocidbtools:ocid1.databasetoolsconnection
```

10.1.4 Built-in Configuration Providers

The JDBC Driver includes two built-in Configuration Providers, one HTTPS Provider and one File provider.

You do not need any extra JAR files for using these providers as they are based on the same JSON Schema as used for OCI Object Storage, that is, the schema is the same for all the JSON based providers, namely, HTTPS, File, and OCI Object Storage.

> **See Also**
>
> Oracle Database JDBC Java API Reference

HTTPS Configuration Provider

You can provide the JSON configuration document through an HTTPS endpoint like Oracle REST Data Services (ORDS). HTTP is not supported because the JSON configuration document may contain multiple aliases, so the URL must end with the alias name that needs to be loaded, for example, `https://<URL>/aliasname`.

You can protect the access to this configuration document using IP ACL, TCPS, and Basic HTTP Authentication.

The JDBC URL follows the following format:

```
jdbc:oracle:thin:@config-https://<URL>[?key=name&option1=value1]
```


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As the `https` prefix is followed by a host, the double slash (`//`) is required after the provider name, whether it is `http` or `https`.

You can configure client authentication with basic HTTP authentication over HTTPS, using wallet through properties, similar to the following example:

```
jdbc:oracle:thin:@config-https://confighost.mydomain.com/oracleconfig?
key=name&authentication=BASIC_AUTH&wallet_location=/path/to/wallet
```

You can use the authentication option to make the HTTP Configuration Provider use the basic HTTP authentication to retrieve the JSON configuration document.

> **Note**
>
> The HTTPS Configuration Provider that Oracle distributes, supports Basic HTTP Authentication.

File Configuration Provider

In this case, the JSON configuration document is provided through the file system and access to this configuration is protected by file system protections. File Configuration Provider, The JDBC URL follows the following format, in case of this Configuration Provider:

```
jdbc:oracle:thin:@config-file:{path-to-file}[?option list]
```

Here, the `{path-to-file}` parameter accepts the same rules as the `java.io.File` class. The option list includes an attribute to indicate the connection key name, for example, `sales_app1` in the following example:

```
jdbc:oracle:thin:@config-file:path/to/file.json?key=sales_app1
```

10.2 Resource Providers

A Resource Provider provides Oracle JDBC with a single resource, such as a password or a connection string.

Resource providers are configured by the connection properties. For example, you can use the following connection properties to configure a password provider:

```
oracle.jdbc.provider.password=example-provider
oracle.jdbc.provider.password.vaultId=9999-8888-7777
```

In the preceding example, the `oracle.jdbc.provider.password` property configures the name of a password provider. The `oracle.jdbc.provider.password.vaultId` property configures a parameter that is recognized by the password provider.

A resource provider may provide any of the following resources:

- Database connection string
- Database user name
- Database password

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- Database access token
- TLS/SSL configuration
- Trace event listener

Corresponding to the list above, the following connection properties identify the name of Resource Provider:

- `oracle.jdbc.provider.connectionString`
- `oracle.jdbc.provider.username`
- `oracle.jdbc.provider.password`
- `oracle.jdbc.provider.accessToken`
- `oracle.jdbc.provider.tlsConfiguration`
- `oracle.jdbc.provider.traceEventListener`

You can also configure additional parameters as connection properties.

See Also

10.3 Trace Event Listener Providers

Starting with Oracle Database Release 23ai, the JDBC driver can generate events that can be used to monitor a JDBC application.

The JDBC driver defines an `oracle.jdbc.spi.TraceEventListenerProvider` interface that can be used to register a custom `TraceEventListener` through the SPI mechanism.

For example, you can use this feature to register a listener that publishes the following events to OpenTelemetry:

- Database round trips during query execution
- Virtual IP address retries while establishing a connection
- Starting of a recovery from a database outage when Application Continuity is used
- Successful recoveries from a database outage when Application Continuity is used

See Also

The JDBC Javadoc for more information

10.4 JDBC Extensions for Cloud Vendors

The Oracle JDBC Driver Extensions include providers for centralized configuration or token providers for authentication with the Database.

These extensions help you in implementing the Service Provider Interfaces (SPIs) for integration with widely used services, such as Cloud computing platforms. The extensions are open-source on GitHub at the following link, and the artifacts are available on Maven Central:

https://github.com/oracle-samples/ojdbc-extensions/tree/main

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For Centralized Configuration Providers, the extensions include providers for the following:

- OCI DBTools connection
- Azure App Configuration

For Resource Providers, these extensions include providers for the following:

- Authentication tokens issued by either OCI IAM (Identity and Access Management) or Azure AD (Active Directory), while using Oracle Autonomous Database Serverless
- The database password or user name stored in an OCI Vault secret or Azure Vault secret
- JDBC URL and client wallet from an Oracle Autonomous Database Serverless for mTLS connections
- JDBC events that are stored in OpenTelemetry

See Also

Oracle JDBC Driver Extensions in GitHub for information

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11

Proxy Authentication

Oracle Java Database Connectivity (JDBC) provides proxy authentication, also called N-tier authentication. This feature is supported through both the JDBC Oracle Call Interface (OCI) driver and the JDBC Thin driver. This chapter contains the following sections:

- About Proxy Authentication
- Types of Proxy Connections
- Creating Proxy Connections
- Closing a Proxy Session
- Caching Proxy Connections
- Limitations of Proxy Connections

> **Note**
>
> Oracle Database supports proxy authentication functionality in three tiers *only*. It does not support it across multiple middle tiers.

11.1 About Proxy Authentication

Proxy authentication is the process of using a middle tier for user authentication.

You can design a middle-tier server to proxy clients in a secure fashion by using the following three forms of proxy authentication:

- The middle-tier server authenticates itself with the database server and a client. In this case, an application user or another application, authenticates itself with the middle-tier server. Client identities can be maintained all the way through to the database.
- The client, that is, a database user, is not authenticated by the middle-tier server. The client's identity and the database password are passed through the middle-tier server to the database server for authentication.
- The client, that is, a global user, is authenticated by the middle-tier server, and passes either a Distinguished name (DN) or a Certificate through the middle tier for retrieving the client's user name.

> **Note**
>
> Operations done on behalf of a client by a middle-tier server can be audited.

In all cases, an administrator must authorize the middle-tier server to proxy a client, that is, to act on behalf of the client. Suppose, the middle-tier server initially connects to the database as

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user HR and activates a proxy connection as a user called, jeff. It then authorizes the middle-tier server to proxy a client:

```
CREATE USER jeff;
ALTER USER jeff GRANT CONNECT THROUGH HR;
```

You can also:

- Specify roles that the middle tier is permitted to activate when connecting as the client. For example,

  ```
  CREATE ROLE role1;
  GRANT SELECT ON employees TO role1;
  GRANT ROLE1 TO jeff;
  ALTER USER jeff GRANT CONNECT THROUGH HR WITH ROLE role1;
  ```

  The role clause limits the access only to those database objects that are mentioned in the list of the roles. The list of roles can be empty.
- Find the users who are currently authorized to connect through a middle tier by querying the PROXY_USERS data dictionary view.
- Disallow a proxy connection by using the REVOKE CONNECT THROUGH clause of ALTER USER statement.

> **Note**
>
> In case of proxy authentication, a JDBC connection to the database creates a database session during authentication, and then other sessions can be created during the life time of the connection.

You need to use the different fields and methods present in the oracle.jdbc.OracleConnection interface to set up the different types of proxy connections.

11.2 Types of Proxy Connections

You can create proxy connections using either a user name or a distinguished name.

- USER NAME

  This is done by supplying the user name or the password or both. The SQL statement for specifying authentication using password is:

  ```
  ALTER USER jeff GRANT CONNECT THROUGH HR AUTHENTICATION REQUIRED;
  ```

  In this case, jeff is the user name and HR is the proxy for jeff.

  The password option exists for additional security. Having no authenticated clause implies default authentication, which is using only the user name without the password. The SQL statement for specifying default authentication is:

  ```
  ALTER USER jeff GRANT CONNECT THROUGH HR
  ```

- DISTINGUISHED NAME

  This is a global name in lieu of the password of the user being proxied for. An example of the corresponding SQL statement using a distinguished name is:

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```
CREATE USER jeff IDENTIFIED GLOBALLY AS
'CN=jeff,OU=americas,O=oracle,L=redwoodshores,ST=ca,C=us';
```

The string that follows the `identified globally as` clause is the distinguished name. It is then necessary to authenticate using this distinguished name. The corresponding SQL statement to specify authentication using distinguished name is:

```
ALTER USER jeff GRANT CONNECT THROUGH HR;
```

Note

- All the options can be associated with roles.
- When opening a new proxied connection, a new session is started on the Database server. If you start a global transaction and then call the `openProxySession` method, then, at this point, you are no longer a part of the global transaction and instead it is like you are in a freshly created JDBC connection. Typically, this never happens because the `openProxySession` method is called prior to creating or resuming a global transaction. In such a case, you are still a part of the global transaction.

11.3 Creating Proxy Connections

A user, say `jeff`, has to connect to the database through another user, say `HR`. The proxy user, `HR`, should have an active authenticated connection. A proxy session is then created on this active connection, with the driver issuing a command to the server to create a session for the user, `jeff`. The server returns the new session ID, and the driver sends a session switch command to switch to this new session.

The JDBC OCI and Thin driver switch sessions in the same manner. The drivers permanently switch to the new session, `jeff`. As a result, the proxy session, `HR`, is not available until the new session, `jeff`, is closed.

Note

You can use the `isProxySession` method from the `oracle.jdbc.OracleConnection` interface to check if the current session associated with your connection is a proxy session. This method returns `true` if the current session associated with the connection is a proxy session.

A new proxy session is opened by using the following method from the `oracle.jdbc.OracleConnection` interface:

```
void openProxySession(int type, java.util.Properties prop) throws SQLExceptionOpens
```

Where,

`type` is the type of the proxy session and can have the following values:

- `OracleConnection.PROXYTYPE_USER_NAME`

  This type is used for specifying the user name.
- `OracleConnection.PROXYTYPE_DISTINGUISHED_NAME`

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This type is used for specifying the distinguished name of the user.

`prop` is the property value of the proxy session and can have the following values:

- `PROXY_USER_NAME`

  This property value should be used with the type `OracleConnection.PROXYTYPE_USER_NAME`. The value should be a `java.lang.String`.

- `PROXY_DISTINGUISHED_NAME`

  This property value should be used with the type `OracleConnection.PROXYTYPE_DISTINGUISHED_NAME`. The value should be a `java.lang.String`.

- `PROXY_ROLES`

  This property value can be used with the following types:

  – `OracleConnection.PROXYTYPE_USER_NAME`

  – `OracleConnection.PROXYTYPE_DISTINGUISHED_NAME`

  The value should be a `java.lang.String`.

- `PROXY_SESSION`

  This property value is used with the `close` method to close the proxy session.

- `PROXY_USER_PASSWORD`

  This property value should be used with the type `OracleConnection.PROXYTYPE_USER_NAME`. The value should be a `java.lang.String`.

The following code snippet shows the use of the `openProxySession` method:

```
java.util.Properties prop = new java.util.Properties();
prop.put(OracleConnection.PROXY_USER_NAME, "jeff");
String[] roles = {"role1", "role2"};
prop.put(OracleConnection.PROXY_ROLES, roles);
conn.openProxySession(OracleConnection.PROXYTYPE_USER_NAME, prop);
```

11.4 Closing a Proxy Session

You can close the proxy session opened with the `OracleConnection.openProxySession` method by passing the `OracleConnection.PROXY_SESSION` parameter to the `OracleConnection.close` method in the following way:

```
OracleConnection.close(OracleConnection.PROXY_SESSION);
```

This is similar to closing a proxy session on a non-cached connection. The standard `close` method must be called explicitly to close the connection itself. If the `close` method is called directly, without closing the proxy session, then both the proxy session and the connection are closed. This can be achieved in the following way:

```
OracleConnection.close(OracleConnection.INVALID_CONNECTION);
```

11.5 Caching Proxy Connections

Proxy connections, like standard connections, can be cached. Caching proxy connections enhances the performance. To cache a proxy connection, you need to create a connection using one of the `getConnection` methods on a cache enabled `OracleDataSource` object.

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A proxy connection may be cached in the connection cache using the connection attributes feature of the connection cache. Connection attributes are name/value pairs that are user-defined and help tag a connection before returning it to the connection cache for reuse. When the tagged connection is retrieved, it can be directly used without having to do a round-trip to create or close a proxy session. Universal Connection Pool supports caching of any user/password authenticated connection. Therefore, any user authenticated proxy connection can be cached and retrieved.

It is recommended that proxy connections should not be closed without applying the connection attributes. If a proxy connection is closed without applying the connection attributes, the connection is returned to the connection cache for reuse, but cannot be retrieved. The connection caching mechanism does not remember or reset session state.

A proxy connection can be removed from the connection cache by closing the connection directly.

11.6 Limitations of Proxy Connections

Closing a proxy connection automatically closes every SQL Statement created by the proxy connection, during the proxy session or prior to the proxy session. This may cause unexpected consequences on application pooling or statement caching. The following code samples explain this limitation of proxy connections:

Example 1

```
....
public void displayName(String N)  // Any function using the Proxy feature
{
     Properties props = new Properties();
     props.put("PROXY_USER_NAME", proxyUser);
     c.openProxySession(OracleConnection.PROXYTYPE_USER_NAME, props);
     .......
     c.close(OracleConnection.PROXY_SESSION);
}

public static void main (String args[]) throws SQLException
{
    ............
    PreparedStatement pstmt = conn.prepareStatement("SELECT first_name FROM EMPLOYEES
WHERE employee_id = ?");
    pstmt.setInt(1, 205);
    ResultSet rs = pstmt.executeQuery();
    while (rs.next())
    {
        displayName(rs.getString(1));
         if (rs.isClosed() // The ResultSet is already closed while closing the
connection!
         {
             throw new Exception("Your ResultSet has been prematurely closed!
Your Statement object is also dead now.");
         }
    }
}
```

In the preceding example, when you close the proxy connection in the `displayName` method, then the `PreparedStatement` object and the `ResultSet` object also get closed. So, if you do not check the status of the `ResultSet` object inside loop, then the loop will fail when the `next` method is called for the second time.

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Example 2

```
    ....
    PreparedStatement pstmt = conn.prepareStatement("SELECT first_name FROM EMPLOYEES
WHERE employee_id = ?");
    pstmt.setString(1, "205");
    ResultSet rs = pstmt.executeQuery();
    while (rs.next())
    {
        ....
    }

    Properties props = new Properties();
    props.put("PROXY_USER_NAME", proxyUser);

    conn.openProxySession(OracleConnection.PROXYTYPE_USER_NAME, props);
    .......
    conn.close(OracleConnection.PROXY_SESSION);

    // Try to use the PreparedStatement again
    pstmt.setString(1, "28960");
// This line of code will fail because the Statement is already closed while closing the
connection!
    rs = pstmt.executeQuery();
```

In the preceding example, the `PreparedStatement` object and the `ResultSet` object work fine before opening the proxy connection. But, if you try to execute the same `PreparedStatement` object after closing the proxy connection, then the statement fails.

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Part IV
Data Access and Manipulation

This part provides a chapter that discusses about accessing and manipulating Oracle data. It also includes chapters that provide information about Java Database Connectivity (JDBC) support for user-defined object types, large object (LOB) and binary file (BFILE) locators and data, object references, and Oracle collections, such as nested tables. This part also provides chapters that discuss the result set functionality in JDBC, JDBC row sets, and globalization support provided by Oracle JDBC drivers.

Part IV contains the following chapters:

- Accessing and Manipulating Oracle Data
- Java Streams in JDBC
- Working with Vectors
- Working with Oracle Object Types
- Working with LOBs and BFILEs
- Using Oracle Object References
- Working with Oracle Collections
- Result Set
- JDBC RowSets
- Globalization Support

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12

Accessing and Manipulating Oracle Data

This chapter describes Oracle extensions (`oracle.sql.*` formats) and compares them to standard Java formats (`java.sql.*`). Using Oracle extensions involves casting your result sets and statements to `OracleResultSet`, `OracleStatement`, `OraclePreparedStatement`, and `OracleCallableStatement`, as appropriate, and using the `getOracleObject`, `setOracleObject`, `get`*`XXX`*, and `set`*`XXX`* methods of these classes, where *`XXX`* corresponds to the types in the `oracle.sql` package.

This chapter covers the following topics:

- Data Type Mappings
- Data Conversion Considerations
- Result Set and Statement Extensions
- Comparison of Oracle get and set Methods to Standard JDBC
- Using Result Set Metadata Extensions
- About Using SQL CALL and CALL INTO Statements

12.1 Data Type Mappings

The Oracle JDBC drivers support standard JDBC types as well as Oracle-specific data types. This section documents standard and Oracle-specific SQL-Java default type mappings. This section contains the following topics:

- Table of Mappings
- Notes Regarding Mappings

12.1.1 Table of Mappings

This section describes the default mappings between SQL data types, JDBC type codes, standard Java types, and Oracle extended types.

The SQL Data Types column lists the SQL types that exist in Oracle Database Release 23ai. The JDBC Type Codes column lists data type codes supported by the JDBC standard and defined in the `java.sql.Types` class or by Oracle in the `oracle.jdbc.OracleTypes` class. For standard type codes, the codes are identical in these two classes.

The Standard Java Types column lists standard types defined in the Java language. The Oracle Extension Java Types column lists the `oracle.sql.*` Java types that correspond to each SQL data type in the database. These are Oracle extensions that let you retrieve all SQL data in the form of an `oracle.sql.*` Java type.

Starting with Oracle Database Release 23ai, the JDBC driver supports the `BOOLEAN` SQL type. So, while connecting to a 23ai Database, when the `setBoolean(x)` or `setObject(x)` method is called, where `x` is a Java `boolean`, the value of `x` is sent using this new `Boolean` type representation. This may break existing applications that store `boolean` values in `VARCHAR` or `TINYINT/NUMBER` types because the server may not always convert a `BOOLEAN` native value to these types. To workaround such situations, use the new connection property,

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`oracle.jdbc.sendBooleanAsNativeBoolean` that controls how the driver sends a `Boolean` parameter to the Database. If you set the value of this property to `false`, then the driver sends a `boolean` bind as a `NUMBER`, like it did in the earlier versions.

> **Note**
>
> In general, the Oracle JDBC drivers are optimized to manipulate SQL data using the standard JDBC types. In a few specialized cases, it may be advantageous to use the Oracle extension classes that are available in the `oracle.sql` package. But, Oracle strongly recommends to use the standard JDBC types instead of Oracle extensions, whenever possible.

Table 12-1 Default Mappings Between SQL Types and Java Types

SQL Data Types	JDBC Type Codes	Standard Java Types	Oracle Extension Java Types
BOOLEAN	java.sql.Types.BOOLEAN	java.lang.Boolean or java.lang.boolean	oracle.sql.BOOLEAN
CHAR	java.sql.Types.CHAR	java.lang.String	oracle.sql.CHAR
VARCHAR2	java.sql.Types.VARCHAR	java.lang.String	oracle.sql.CHAR
LONG	java.sql.Types.LONGVARCHAR	java.lang.String	oracle.sql.CHAR
NUMBER	java.sql.Types.NUMERIC	java.math.BigDecimal	oracle.sql.NUMBER
NUMBER	java.sql.Types.DECIMAL	java.math.BigDecimal	oracle.sql.NUMBER
NUMBER	java.sql.Types.BIT	boolean	oracle.sql.NUMBER
NUMBER	java.sql.Types.TINYINT	byte	oracle.sql.NUMBER
NUMBER	java.sql.Types.SMALLINT	short	oracle.sql.NUMBER
NUMBER	java.sql.Types.INTEGER	int	oracle.sql.NUMBER
NUMBER	java.sql.Types.BIGINT	long	oracle.sql.NUMBER
NUMBER	java.sql.Types.REAL	float	oracle.sql.NUMBER
NUMBER	java.sql.Types.FLOAT	double	oracle.sql.NUMBER
NUMBER	java.sql.Types.DOUBLE	double	oracle.sql.NUMBER
RAW	java.sql.Types.BINARY	byte[]	oracle.sql.RAW
RAW	java.sql.Types.VARBINARY	byte[]	oracle.sql.RAW
LONGRAW	java.sql.Types.LONGVARBINARY	byte[]	oracle.sql.RAW
DATE	java.sql.Types.DATE	java.sql.Date	oracle.sql.DATE
DATE	java.sql.Types.TIME	java.sql.Time	oracle.sql.DATE
TIMESTAMP	java.sql.Types.TIMESTAMP	javal.sql.Timestamp	oracle.sql.TIMESTAMP
BLOB	java.sql.Types.BLOB	java.sql.Blob	oracle.jdbc.OracleBlob
CLOB	java.sql.Types.CLOB	java.sql.Clob	oracle.jdbc.OracleClob
user-defined object	java.sql.Types.STRUCT	java.sql.Struct	oracle.jdbc.OracleStruct[1]
user-defined reference	java.sql.Types.REF	java.sql.Ref	oracle.jdbc.OracleRef
user-defined collection	java.sql.Types.ARRAY	java.sql.Array	oracle.jdbc.OracleArray[2]

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Table 12-1 (Cont.) Default Mappings Between SQL Types and Java Types

SQL Data Types	JDBC Type Codes	Standard Java Types	Oracle Extension Java Types
ROWID	java.sql.Types.ROWID	java.sql.RowId	oracle.sql.ROWID
NCLOB	java.sql.Types.NCLOB	java.sql.NClob	oracle.sql.NCLOB
NCHAR	java.sql.Types.NCHAR	java.lang.String	oracle.sql.CHAR
BFILE	oracle.jdbc.OracleTypes.BFILE (ORACLE EXTENSION)	NA	oracle.sql.BFILE
REF CURSOR	oracle.jdbc.OracleTypes.CURSOR (ORACLE EXTENSION)	java.sql.ResultSet	oracle.jdbc.OracleResultSet
TIMESTAMP	oracle.jdbc.OracleTypes.TIMESTAMP (ORACLE EXTENSION)	java.sql.Timestamp	oracle.sql.TIMESTAMP
TIMESTAMP WITH TIME ZONE	oracle.jdbc.OracleTypes.TIMESTAMPTZ (ORACLE EXTENSION)	java.sql.Timestamp	oracle.sql.TIMESTAMPTZ
TIMESTAMP WITH LOCAL TIME ZONE	oracle.jdbc.OracleTypes.TIMESTAMPLTZ (ORACLE EXTENSION)	java.sql.Timestamp	oracle.sql.TIMESTAMPLTZ

1

2

Related Topics

- Standard Types Versus Oracle Types
- Supported SQL-JDBC Data Type Mappings
  This section lists all the possible Java types to which a given SQL data type can have a valid mapping.

12.1.2 Notes Regarding Mappings

This section provides further details regarding mappings for NUMBER and user-defined types.

NUMBER Types

For the different type codes that an Oracle NUMBER value can correspond to, call the getter routine that is appropriate for the size of the data for mapping to work properly. For example, call getByte to get a Java tinyint value for an item *x*, where -128 < *x* < 128.

User-Defined Types

User-defined types, such as objects, object references, and collections, map by default to weak Java types, such as java.sql.Struct, but alternatively can map to strongly typed custom Java classes. Custom Java classes can implement one of two interfaces:

- The standard java.sql.SQLData
- The Oracle-specific oracle.jdbc.OracleData

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Related Topics

- About Mapping Oracle Objects
- About Creating and Using Custom Object Classes for Oracle Objects

12.2 Data Conversion Considerations

When JDBC programs retrieve SQL data into Java, you can use standard Java types, or you can use types of the `oracle.sql` package. This section covers the following topics:

- Standard Types Versus Oracle Types
- About Converting SQL NULL Data
- About Testing for NULLs

12.2.1 Standard Types Versus Oracle Types

The Oracle data types in `oracle.sql` store data in the same bit format as used by the database. In versions of the Oracle JDBC drivers prior to Oracle Database 10*g*, the Oracle data types were generally more efficient. Starting from Oracle Database 10*g*, the JDBC drivers were substantially updated. As a result, in most cases the standard Java types are preferred to the data types in `oracle.sql.*`. In particular, `java.lang.String` is much more efficient than `oracle.sql.CHAR`.

In general, Oracle recommends that you use the Java standard types. The exceptions to this are:

- Use the `oracle.jdbc.OracleData` rather than the `java.sql.SqlData` if the `OracleData` functionality better suits your needs.
- Use `oracle.sql.NUMBER` rather than `java.lang.Double` if you need to retain the exact values of floating point numbers. Oracle `NUMBER` is a decimal representation and Java `Double` and `Float` are binary representations. Conversion from one format to the other can result in slight variations in the actual value represented. Additionally, the range of values that can be represented using the two formats is different.

  Use `oracle.sql.NUMBER` rather than `java.math.BigDecimal` when performance is critical and you are not manipulating the values, just reading and writing them.
- Use `oracle.sql.DATE` or `oracle.sql.TIMESTAMP` if you are using a JDK version earlier than JDK 6. Use `java.sql.Date` or `java.sql.Timestamp` if you are using JDK 6 or a later version.

  > **Note**
  >
  > Due to a bug in all versions of Java prior to JDK 6, construction of `java.lang.Date` and `java.lang.Timestamp` objects is slow, especially in multithreaded environments. This bug is fixed in JDK 6.

- Use `oracle.sql.CHAR` only when you have data from some external source, which has been represented in an Oracle character set encoding. In all other cases, you should use `java.lang.String`.
- `STRUCT`, `ARRAY`, `BLOB`, `CLOB`, `REF`, and `ROWID` are all the implementation classes of the corresponding JDBC standard interface types. So, there is no benefit of using the Oracle extension types as they are identical to the JDBC standard types.

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- `BFILE`, `TIMESTAMPTZ`, and `TIMESTAMPLTZ` have no representation in the JDBC standard. You must use these Oracle extensions.
- In all other cases, you should use the standard JDBC type rather than the Oracle extensions.

> **Note**
>
> If you convert an `oracle.sql` data type to a Java standard data type, then the benefits of using the `oracle.sql` data type are lost.

12.2.2 About Converting SQL NULL Data

Java represents a SQL `NULL` datum by the Java value `null`. Java data types fall into two categories: primitive types, such as `byte`, `int`, and `float`, and object types, such as class instances. The primitive types cannot represent `null`. Instead, they store `null` as the value zero, as defined by the JDBC specification. This can lead to ambiguity when you try to interpret your results.

In contrast, Java object types can represent `null`. The Java language defines an object container type corresponding to every primitive type that can represent `null`. The object container types must be used as the targets for SQL data to detect SQL `NULL` without ambiguity.

12.2.3 About Testing for NULLs

You cannot use a relational operator to compare `NULL` values with each other or with other values. For example, the following `SELECT` statement does not return any row even if the `COMMISSION_PCT` column contains one or more `NULL` values.

```
PreparedStatement pstmt = conn.prepareStatement(
  "SELECT * FROM EMPLOYEES WHERE COMMISSION_PCT = ?");
pstmt.setNull(1, java.sql.Types.VARCHAR);
```

The next example shows how to compare values for equality when some return values might be `NULL`. The following code returns all the `FIRST_NAME` from the `EMPLOYEES` table that are `NULL`, if there is no value of 205 for `COMM`.

```
PreparedStatement pstmt = conn.prepareStatement("SELECT FIRST_NAME FROM EMPLOYEES
  WHERE COMMISSION_PCT =? OR  ((COMM IS NULL) AND (? IS NULL))");
pstmt.setBigDecimal(1, new BigDecimal(205));
pstmt.setNull(2, java.sql.Types.VARCHAR);
```

12.3 Result Set and Statement Extensions

The `Statement` object returns a `java.sql.ResultSet`. If you want to apply only standard JDBC methods to the object, then keep it as a `ResultSet` type. However, if you want to use the Oracle extensions on the object, then you must cast it to `OracleResultSet`. All of the Oracle Result Set extensions are in the `oracle.jdbc.OracleResultSet` interface and all the `Statement` extensions are in the `oracle.jdbc.OracleStatement` interface.

For example, assuming you have a standard `Statement` object `stmt`, do the following if you want to use only standard JDBC `ResultSet` methods:

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```
ResultSet rs = stmt.executeQuery("SELECT * FROM employees");
```

If you need the extended functionality provided by the Oracle extensions to JDBC, you can select the results into a standard `ResultSet` variable and then cast that variable to `OracleResultSet` later.

Key extensions to the result set and statement classes include the `getOracleObject` and `setOracleObject` methods, used to access and manipulate data in `oracle.sql.*` formats.

12.4 Comparison of Oracle get and set Methods to Standard JDBC

This section describes `get` and `set` methods, particularly the JDBC standard `getObject` and `setObject` methods and the Oracle-specific `getOracleObject` and `setOracleObject` methods, and how to access data in `oracle.sql.*` format compared with Java format.

You can use the standard `get`*`XXX`* methods for all Oracle SQL types.

This section covers the following topics:

- Standard getObject Method
- Oracle getOracleObject Method
- Summary of getObject and getOracleObject Return Types
- Other getXXX Methods
- Data Types For Returned Objects from getObject and getXXX
- The setObject and setOracleObject Methods
- Other setXXX Methods

> **Note**
>
> You cannot qualify a column name with a table name and pass it as a parameter to the `get`*`XXX`* method. For example:
>
> ```
> ResultSet rset = stmt.executeQuery("SELECT employees.department_id,
> department.department_id FROM employees, department");
> rset.getInt("employees.department_id");
> ```
>
> The `getInt` method in the preceding code will throw an exception. To uniquely identify the columns in the `get`*`XXX`* method, you can either use column index or specify column aliases in the query and use these aliases in the `get`*`XXX`* method.

12.4.1 Standard getObject Method

The standard `getObject` method of a result set or callable statement has a return type of `java.lang.Object`. The class of the object returned is based on its SQL type, as follows:

- For SQL data types that are not Oracle-specific, the `getObject` method returns the default Java type corresponding to the SQL type of the column, following the mapping in the JDBC specification.

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- For Oracle-specific data types, `getObject` returns an object of the appropriate `oracle.sql.*` class, such as `oracle.sql.ROWID`.
- For Oracle database objects, `getObject` returns a Java object of the class specified in your type map. Type maps specify a mapping from database named types to Java classes. The `getObject(parameter_index)` method uses the default type map of the connection. The `getObject(parameter_index, map)` enables you to pass in a type map. If the type map does not provide a mapping for a particular Oracle object, then `getObject` returns an `oracle.sql.OracleStruct` object.

12.4.2 Oracle getOracleObject Method

If you want to retrieve data from a result set or callable statement as an `oracle.sql.*` object, then you must follow a special process. For an `OracleResultSet` object, you must cast the Result Set to `oracle.jdbc.OracleResultSet` and then call `getOracleObject` instead of `getObject`. The same applies to `CallableStatement` and `oracle.jdbc.OracleCallableStatement`.

The return type of `getOracleObject` is `oracle.sql.Datum`. The actual returned object is an instance of the appropriate `oracle.sql.*` class. The method signature is:

```
public oracle.sql.Datum getOracleObject(int parameter_index)
```

When you retrieve data into a `Datum` variable, you can use the standard Java `instanceof` operator to determine which `oracle.sql.*` type it really is.

Example: Using getOracleObject with a Result Set

The following example creates a table that contains a column of `CHAR` data and a column containing a `BFILE` locator. A `SELECT` statement retrieves the contents of the table as a result set. The `getOracleObject` then retrieves the `CHAR` data into the `char_datum` variable and the `BFILE` locator into the `bfile_datum` variable. Note that because `getOracleObject` returns a `Datum` object, the return values must be cast to `CHAR` and `BFILE`, respectively.

```
stmt.execute ("CREATE TABLE bfile_table (x VARCHAR2 (30), b BFILE)");
stmt.execute
    ("INSERT INTO bfile_table VALUES ('one', BFILENAME ('TEST_DIR', 'file1'))");

ResultSet rset = stmt.executeQuery ("SELECT * FROM bfile_table");
while (rset.next ())
{
   CHAR char_datum = (CHAR) ((OracleResultSet)rset).getOracleObject (1);
   BFILE bfile_datum = (BFILE) ((OracleResultSet)rset).getOracleObject (2);
   ...
}
```

Example: Using getOracleObject in a Callable Statement

The following example prepares a call to the procedure `myGetDate`, which associates a character string with a date. The program passes `"HR"` to the prepared call and registers the `DATE` type as an output parameter. After the call is run, `getOracleObject` retrieves the date associated with `"HR"`. Note that because `getOracleObject` returns a `Datum` object, the results are cast to `DATE`.

```
OracleCallableStatement cstmt = (OracleCallableStatement)conn.prepareCall
                                    ("begin myGetDate (?, ?); end;");

cstmt.setString (1, "HR");
cstmt.registerOutParameter (2, Types.DATE);
```


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```
cstmt.execute ();

DATE date = (DATE) ((OracleCallableStatement)cstmt).getOracleObject (2);
...
```

12.4.3 Summary of getObject and getOracleObject Return Types

This section lists the underlying return types for the `getObject` and `getOracleObject` methods for each Oracle SQL type.

Keep in mind the following when you use these methods:

- `getObject` always returns data into a `java.lang.Object` instance
- `getOracleObject` always returns data into an `oracle.sql.Datum` instance

You must cast the returned object to use any special functionality.

Table 12-2 getObject and getOracleObject Return Types

Oracle SQL Type	getObject Underlying Return Type	getOracleObject Underlying Return Type
CHAR	String	oracle.sql.CHAR
VARCHAR2	String	oracle.sql.CHAR
NCHAR	String	oracle.sql.CHAR
LONG	String	oracle.sql.CHAR
NUMBER	java.math.BigDecimal	oracle.sql.NUMBER
RAW	byte[]	oracle.sql.RAW
LONGRAW	byte[]	oracle.sql.RAW
DATE	java.sql.Date	oracle.sql.DATE
TIMESTAMP	java.sql.Timestamp[1]	oracle.sql.TIMESTAMP
TIMESTAMP WITH TIME ZONE	oracle.sql.TIMESTAMPTZ	oracle.sql.TIMESTAMPTZ
TIMESTAMP WITH LOCAL TIME ZONE	oracle.sql.TIMESTAMPLTZ	oracle.sql.TIMESTAMPLTZ
BINARY_FLOAT	java.lang.Float	oracle.sql.BINARY_FLOAT
BINARY_DOUBLE	java.lang.Double	oracle.sql.BINARY_DOUBLE
INTERVAL DAY TO SECOND	oracle.sql.INTERVALDS	oracle.sql.INTERVALDS
INTERVAL YEAR TO MONTH	oracle.sql.INTERVALYM	oracle.sql.INTERVALYM
ROWID	oracle.sql.ROWID	oracle.sql.ROWID
REF CURSOR	java.sql.ResultSet	(not supported)
BLOB	oracle.jdbc.OracleBlob[2]	oracle.jdbc.OracleBlob
CLOB	oracle.jdbc.OracleClob[3]	oracle.jdbc.OracleClob
NCLOB	java.sql.NClob	oracle.sql.NCLOB
BFILE	oracle.sql.BFILE	oracle.sql.BFILE

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Table 12-2 (Cont.) getObject and getOracleObject Return Types

Oracle SQL Type	getObject Underlying Return Type	getOracleObject Underlying Return Type
Oracle object	class specified in type map or `oracle.sql.OracleStruct`[4] (if no type map entry)	`oracle.jdbc.OracleStruct`
Oracle object reference	`oracle.jdbc.OracleRef`[5]	`oracle.jdbc.OracleRef`
collection (varray or nested table)	`oracle.jdbc.OracleArray`[6]	`oracle.sql.ARRAY`

1 `ResultSet.getObject` returns `java.sql.Timestamp` only if the `oracle.jdbc.J2EE13Compliant` connection property is set to `TRUE`, else the method returns `oracle.sql.TIMESTAMP`.

2 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.BLOB` class is deprecated and replaced with the `oracle.jdbc.OracleBlob` interface.

3 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.CLOB` class is deprecated and replaced with the `oracle.jdbc.OracleClob` interface.

4 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.STRUCT` class is deprecated and replaced with the `oracle.jdbc.OracleStruct` interface.

5 Starting from Oracle Database 12*c* Release 1, the `oracle.sql.REF` class is deprecated and is replaced with the `oracle.jdbc.OracleRef` interface.

6 Starting from Oracle Database 12*c* Release 1, the `oracle.sql.ARRAY` class is deprecated and replaced with the `oracle.jdbc.OracleArray` interface.

Note

The `ResultSet.getObject` method returns `java.sql.Timestamp` for the `TIMESTAMP` SQL type, only when the connection property `oracle.jdbc.J2EE13Compliant` is set to `TRUE`. This property has to be set when the connection is obtained. If this connection property is not set or if it is set after the connection is obtained, then the `ResultSet.getObject` method returns `oracle.sql.TIMESTAMP` for the `TIMESTAMP` SQL type.

The `oracle.jdbc.J2EE13Compliant` connection property can also be set without changing the code. For this, set the system property by calling the `java` command with the flag `-Doracle.jdbc.J2EE13Compliant=true`. For example:

```
java -Doracle.jdbc.J2EE13Compliant=true ...
```

When the `J2EE13Compliant` property is set to `TRUE`, then the action is similar to Table B-3 of the JDBC specification.

Related Topics

- Supported SQL-JDBC Data Type Mappings
  This section lists all the possible Java types to which a given SQL data type can have a valid mapping.

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12.4.4 Other getXXX Methods

Standard JDBC provides a `get`*`XXX`* for each standard Java type, such as `getByte`, `getInt`, `getFloat`, and so on. Each of these returns exactly what the method name implies.

In addition, the `OracleResultSet` and `OracleCallableStatement` interfaces provide a full complement of `get`*`XXX`* methods corresponding to all the `oracle.sql.*` types. Each `get`*`XXX`* method returns an `oracle.sql.`*`XXX`* object. For example, `getROWID` returns an `oracle.sql.ROWID` object.

There is no performance advantage in using the specific `get`*`XXX`* methods. However, they do save you the trouble of casting, because the return type is specific to the object being returned.

This section covers the following topics:

- Return Types of getXXX Methods
- Special Notes about getXXX Methods

12.4.4.1 Return Types of getXXX Methods

Refer to the JDBC Javadoc to know the return types for each `get`*`XXX`* method and also which are Oracle extensions under Java Development Kit (JDK) 6. You must cast the returned object to `OracleResultSet` or `OracleCallableStatement` to use methods that are Oracle extensions.

12.4.4.2 Special Notes about getXXX Methods

This section provides additional details about some `get`*`XXX`* methods.

getBigDecimal

JDBC 2.0 simplified method signatures for the `getBigDecimal` method. The previous input signatures were:

```
(int columnIndex, int scale) or (String columnName, int scale)
```

The simplified input signature is:

```
(int columnIndex) or (String columnName)
```

The `scale` parameter, used to specify the number of digits to the right of the decimal, is no longer necessary. The Oracle JDBC drivers retrieve numeric values with full precision.

getBoolean

If the column from which you are trying to fetch the data is not of `BOOLEAN` type, which is introduced in Oracle Database 23ai Release, then the use of the `getBoolean` method results in a data type conversion. Apart from the `BOOLEAN` type, the `getBoolean` method also supports the following columns:

- `INT`
- `CHAR`
- `NCHAR`
- `NUMBER`
- `VARCHAR`

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- NVARCHAR

When you apply this method to the supported data types, then the `getBoolean` method interprets any zero value as `false` and any other value as `true`. When applied to any other column, apart from the supported columns, the `getBoolean` method raises the exception `java.lang.NumberFormatException`.

> **See Also**
>
> Class oracle.jdbc.OracleTypes for more information about the `BOOLEAN` data type

12.4.5 Data Types For Returned Objects from getObject and getXXX

The return type of `getObject` is `java.lang.Object`. The returned value is an instance of a subclass of `java.lang.Object`. Similarly, the return type of `getOracleObject` is `oracle.sql.Datum`, and the class of the returned value is a subclass of `oracle.sql.Datum`. You typically cast the returned object to the appropriate class to use particular methods and functionality of that class.

In addition, you have the option of using a specific `get`*`XXX`* method instead of the generic `getObject` or `getOracleObject` methods. The `get`*`XXX`* methods enable you to avoid casting, because the return type of `get`*`XXX`* corresponds to the type of object returned. For example, the return type of `getCLOB` is `oracle.sql.CLOB`, as opposed to `java.lang.Object`.

Example of Casting Return Values

This example assumes that you have fetched data of the `NUMBER` type as the first column of a result set. Because you want to manipulate the `NUMBER` data without losing precision, cast your result set to `OracleResultSet` and use `getOracleObject` to return the `NUMBER` data in `oracle.sql.*` format. If you do not cast your result set, then you have to use `getObject`, which returns your numeric data into a Java `Float` and loses some of the precision of your SQL data.

The `getOracleObject` method returns an `oracle.sql.NUMBER` object into an `oracle.sql.Datum` return variable unless you cast the output. Cast the `getOracleObject` output to `oracle.sql.NUMBER` if you want to use a `NUMBER` return variable and any of the special functionality of that class.

```
NUMBER x = (NUMBER)ors.getOracleObject(1);
```

12.4.6 The setObject and setOracleObject Methods

Just as there is a standard `getObject` and Oracle-specific `getOracleObject` in result sets and callable statements, there are also standard `setObject` and Oracle-specific `setOracleObject` methods in `OraclePreparedStatement` and `OracleCallableStatement`. The `setOracleObject` methods take `oracle.sql.*` input parameters.

To bind standard Java types to a prepared statement or callable statement, use the `setObject` method, which takes a `java.lang.Object` as input. The `setObject` method does support a few of the `oracle.sql.*` types. However, the method has been implemented so that you can enter instances of the `oracle.sql.*` classes that correspond to the following JDBC standard types: `Blob`, `Clob`, `Struct`, `Ref`, and `Array`.

To bind `oracle.sql.*` types to a prepared statement or callable statement, use the `setOracleObject` method, which takes a subclass of `oracle.sql.Datum` as input. To use

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`setOracleObject`, you must cast your prepared statement or callable statement to `OraclePreparedStatement` or `OracleCallableStatement`.

Example of Using setObject and setOracleObject

For a prepared statement, the `setOracleObject` method binds the `oracle.sql.CHAR` data represented by the `charVal` variable to the prepared statement. To bind the `oracle.sql.*` data, the prepared statement must be cast to `OraclePreparedStatement`. Similarly, the `setObject` method binds the Java `String` data represented by the variable `strVal`.

```
PreparedStatement ps= conn.prepareStatement("text_of_prepared_statement");
((OraclePreparedStatement)ps).setOracleObject(1,charVal);
ps.setObject(2,strVal);
```

12.4.7 Other setXXX Methods

As with the `getXXX` methods, there are several specific `setXXX` methods. Standard `setXXX` methods are provided for binding standard Java types, and Oracle-specific `setXXX` methods are provided for binding Oracle-specific types.

Similarly, there are two forms of the `setNull` method:

- `void setNull(int parameterIndex, int sqlType)`

  This is specified in the standard `java.sql.PreparedStatement` interface. This signature takes a parameter index and a SQL type code defined by the `java.sql.Types` or `oracle.jdbc.OracleTypes` class. Use this signature to set an object other than a `REF`, `ARRAY`, or `STRUCT` to `NULL`.

- `void setNull(int parameterIndex, int sqlType, String sql_type_name)`

  With JDBC 2.0, this signature is also specified in the standard `java.sql.PreparedStatement` interface. This method takes a SQL type name in addition to a parameter index and a SQL type code. Use this method when the SQL type code is `java.sql.Types.REF`, `ARRAY`, or `STRUCT`. If the type code is other than `REF`, `ARRAY`, or `STRUCT`, then the given SQL type name is ignored.

Similarly, the `registerOutParameter` method has a signature for use with `REF`, `ARRAY`, or `STRUCT` data:

```
void registerOutParameter
            (int parameterIndex, int sqlType, String sql_type_name)
```

Binding Oracle-specific types using the appropriate `setXXX` methods, instead of the methods used for binding standard Java types, may offer some performance advantage.

This section covers the following topics:

- Input Data Binding
- Method setFixedCHAR for Binding CHAR Data into WHERE Clauses

12.4.7.1 Input Data Binding

There are three way to bind data for input:

- Direct binding where the data itself is placed in a bind buffer
- Stream binding where the data is streamed

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- LOB binding where a temporary lob is created, the data placed in the LOB using the LOB APIs, and the bytes of the LOB locator are placed in the bind buffer

The three kinds of binding have some differences in performance and have an impact on batching. Direct binding is fast and batching is fine. Stream binding is slower, may require multiple round trips, and turns batching off. LOB binding is very slow and requires many round trips. Batching works, but might be a bad idea. They also have different size limits, depending on the type of the SQL statement.

For SQL parameters, the length of standard parameter types, such as `RAW` and `VARCHAR2`, is fixed by the size of the target column. For PL/SQL parameters, the size is limited to a fixed number of bytes, which is 32766.

In Oracle Database 10*g* release 2, certain changes were made to the `setString`, `setCharacterStream`, `setAsciiStream`, `setBytes`, and `setBinaryStream` methods of `PreparedStatement`. The original behavior of these APIs were:

- `setString`: Direct bind of characters
- `setCharacterStream`: Stream bind of characters
- `setAsciiStream`: Stream bind of bytes
- `setBytes`: Direct bind of bytes
- `setBinaryStream`: Stream bind of bytes

Starting from Oracle Database 10*g* Release 2, automatic switching between binding modes, based on the data size and on the type of the SQL statement is provided.

setBytes and setBinaryStream

For SQL, direct bind is used for size up to 2000 and stream bind for larger.

For PL/SQL direct bind is used for size up to 32766 and LOB bind is used for larger.

setString, setCharacterStream, and setAsciiStream

For SQL, direct bind is used up to 32766 Java characters and stream bind is used for larger. This is independent of character set.

For PL/SQL, you must be careful about the byte size of the character data in the database character set or the national character set depending on the setting of the form of use parameter. Direct bind is used for data where the byte length is less than 32766 and LOB bind is used for larger.

For fixed length character sets, multiply the length of the Java character data by the fixed character size in bytes and compare that to the restrictive values. For variable length character sets, there are three cases based on the Java character length, as follows:

- If character length is less than 32766 divided by the maximum character size, then direct bind is used.
- If character length is greater than 32766 divided by the minimum character size, then LOB bind is used.
- If character length is in between and if the actual length of the converted bytes is less than 32766, then direct bind is used, else LOB bind is used.

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> **Note**
>
> When a PL/SQL procedure is embedded in a SQL statement, the binding action is different.

The server-side internal driver has the following additional limitations:

- `setString`, `setCharacterStream`, and `setASCIIStream` APIs are not supported for SQL CLOB columns when the data size in characters is over 32767 bytes
- `setBytes` and `setBinaryStream` APIs are not supported for SQL BLOB columns when the data size is over 32767 bytes

> **Note**
>
> Do not use these APIs with the server-side internal driver, without careful checking of the data size in client code.

Related Topics

- Data Interface for LOBs
  The data interface for LOBs includes a set of Java and OCI APIs that are extended to work with LOB data types.

> **See Also**
>
> JDBC Release Notes for further discussion and possible workarounds

12.4.7.2 Method setFixedCHAR for Binding CHAR Data into WHERE Clauses

`CHAR` data in the database is padded to the column width. This leads to a limitation in using the `setCHAR` method to bind character data into the `WHERE` clause of a `SELECT` statement. The character data in the `WHERE` clause must also be padded to the column width to produce a match in the `SELECT` statement. This is especially troublesome if you do not know the column width.

To remedy this, Oracle has added the `setFixedCHAR` method to the `OraclePreparedStatement` class. This method runs a non-padded comparison.

> **Note**
>
> - Remember to cast your prepared statement object to `OraclePreparedStatement` to use the `setFixedCHAR` method.
> - There is no need to use `setFixedCHAR` for an `INSERT` statement. The database always automatically pads the data to the column width as it inserts it.

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Example

The following example demonstrates the difference between the `setCHAR` and `setFixedCHAR` methods.

```
/* Schema is :
 create table my_table (col1 char(10));
 insert into my_table values ('JDBC');
*/
 PreparedStatement pstmt = conn.prepareStatement
                   ("select count(*) from my_table where col1 = ?");

 pstmt.setString (1, "JDBC");  // Set the Bind Value
 runQuery (pstmt);             // This will print " No of rows are 0"

 CHAR ch = new CHAR("JDBC      ", null);
 ((OraclePreparedStatement)pstmt).setCHAR(1, ch); // Pad it to 10 bytes
 runQuery (pstmt);             // This will print "No of rows are 1"

 ((OraclePreparedStatement)pstmt).setFixedCHAR(1, "JDBC");
  runQuery (pstmt);            // This will print "No of rows are 1"

 void runQuery (PreparedStatement ps)
 {
   // Run the Query
   ResultSet rs = pstmt.executeQuery ();

   while (rs.next())
     System.out.println("No of rows are " + rs.getInt(1));

   rs.close();
   rs = null;
 }
```

12.5 Using Result Set Metadata Extensions

The `oracle.jdbc.OracleResultSetMetaData` interface is JDBC 2.0-compliant but does not implement the `getSchemaName` and `getTableName` methods because Oracle Database does not make this feasible.

The following code snippet uses several of the methods in the `OracleResultSetMetadata` interface to retrieve the number of columns from the `EMPLOYEES` table and the numerical type and SQL type name of each column:

```
DatabaseMetaData dbmd = conn.getMetaData();
ResultSet rset = dbmd.getTables("", "HR", "EMPLOYEES", null);

 while (rset.next())
 {
   OracleResultSetMetaData orsmd = ((OracleResultSet)rset).getMetaData();
   int numColumns = orsmd.getColumnCount();
   System.out.println("Num of columns = " + numColumns);

   for (int i=0; i<numColumns; i++)
   {
     System.out.print ("Column Name=" + orsmd.getColumnName (i+1));
     System.out.print (" Type=" + orsmd.getColumnType (i + 1) );
     System.out.println (" Type Name=" + orsmd.getColumnTypeName (i + 1));
  }
}
```


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The program returns the following output:

```
Num of columns = 5
Column Name=TABLE_CAT Type=12 Type Name=VARCHAR2
Column Name=TABLE_SCHEM Type=12 Type Name=VARCHAR2
Column Name=TABLE_NAME Type=12 Type Name=VARCHAR2
Column Name=TABLE_TYPE Type=12 Type Name=VARCHAR2
Column Name=TABLE_REMARKS Type=12 Type Name=VARCHAR2
```

12.6 About Using SQL CALL and CALL INTO Statements

You can use the CALL statement to execute a routine from within SQL in the following two ways:

> **Note**
>
> A routine is a procedure or a function that is standalone or is defined within a type or package. You must have `EXECUTE` privilege on the standalone routine or on the type or package in which the routine is defined.

- By issuing a call to the routine itself by name or by using the `routine_clause`
- By using an `object_access_expression` inside the type of an expression

You can specify one or more arguments to the routine, if the routine takes arguments. You can use positional, named, or mixed notation for argument.

CALL INTO Statement

The `INTO` clause applies only to calls to functions. You can use the following types of variables with this clause:

- Host variable
- Indicator variable

> **See Also**
>
> *Oracle AI Database SQL Language Reference* for more information

PL/SQL Blocks

The basic unit in PL/SQL is a block. All PL/SQL programs are made up of blocks, which can be nested within each other. A PL/SQL block has three parts: a declarative part, an executable part, and an exception-handling part. You get the following advantages by using PL/SQL blocks in your application:

- Better performance
- Higher productivity
- Full portability
- Tight integration with Oracle
- Tight security

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13

Java Streams in JDBC

This chapter describes how the Oracle Java Database Connectivity (JDBC) drivers handle Java streams for several data types. Data streams enable you to read `LONG` column data of up to 2 gigabytes (GB).

This chapter covers the following topics:

- Overview of Java Streams
- About Streaming LONG or LONG RAW Columns
- About Streaming CHAR_ VARCHAR_ or RAW Columns
- About Streaming LOBs and External Files
- Relation Between Data Streaming and Multiple Columns
- Relation Between Streaming and Row Prefetching
- Closing a Stream
- Notes and Precautions on Streams

13.1 Overview of Java Streams

Oracle JDBC drivers support the manipulation of data streams in either direction between server and client. The drivers support all stream conversions: binary, ASCII, and Unicode. Following is a brief description of each type of stream:

- Binary

  Used for `RAW` bytes of data, and corresponds to the `getBinaryStream` method

- ASCII

  Used for ASCII bytes in ISO-Latin-1 encoding, and corresponds to the `getAsciiStream` method

- Unicode

  Used for Unicode bytes with the `UTF-16` encoding, and corresponds to the `getUnicodeStream` method

The `getBinaryStream`, `getAsciiStream`, and `getUnicodeStream` methods return the bytes of data in an `InputStream` object.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `CONNECTION_PROPERTY_STREAM_CHUNK_SIZE` is deprecated and the driver does not use it internally for setting the stream chunk size.

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> **See Also**
>
> Working with LOBs and BFILEs

13.2 About Streaming LONG or LONG RAW Columns

This section covers the following topics:

- Overview of Streaming LONG or LONG RAW Columns
- LONG RAW Data Conversions
- LONG Data Conversions
- Examples:Streaming LONG RAW Data
- About Avoiding Streaming for LONG or LONG RAW

13.2.1 Overview of Streaming LONG or LONG RAW Columns

When a query selects one or more `LONG` or `LONG RAW` columns, the JDBC driver transfers these columns to the client in streaming mode. In streaming mode, the JDBC driver does not read the column data from the network for `LONG` or `LONG RAW` columns, until required. The column data remains in the network communications channel until your code calls a `getXXX` method to read the column data. Even after the call, the column data is read only as needed to populate return value from the getXXX call. Because the column data remains in the communications channel, the streaming mode interferes with all other use of the connection. Any use of the connection, other than reading the column data, will discard the column data from the channel. While the streaming mode makes efficient use of memory and minimizes network round trips, it interferes with many other database operations.

> **Note**
>
> Oracle recommends avoiding `LONG` and `LONG RAW` columns. Use `LOB` instead.

To access the data in a `LONG` column, you can get the column as a Java `InputStream` object and use the `read` method of the `InputStream` object. As an alternative, you can get the data as a `String` or `byte` array. In this case, the driver will do the streaming for you.

You can get `LONG` and `LONG RAW` data with any of the three stream types. The driver performs conversions for you, depending on the character set of the database and the driver.

> **Note**
>
> Do not create tables with `LONG` columns. Use large object (LOB) columns, `CLOB`, `NCLOB`, and `BLOB`, instead. `LONG` columns are supported only for backward compatibility. Oracle recommends that you convert existing `LONG` columns to `LOB` columns. `LOB` columns are subject to far fewer restrictions than `LONG` columns.

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13.2.2 LONG RAW Data Conversions

A call to `getBinaryStream` returns `RAW` data. A call to `getAsciiStream` converts the `RAW` data to hexadecimal and returns the ASCII representation. A call to `getUnicodeStream` converts the `RAW` data to hexadecimal and returns the Unicode characters.

13.2.3 LONG Data Conversions

When you get `LONG` data with `getAsciiStream`, the drivers assume that the underlying data in the database uses an `US7ASCII` or `WE8ISO8859P1` character set. If the assumption is true, then the drivers return bytes corresponding to ASCII characters. If the database is not using an `US7ASCII` or `WE8ISO8859P1` character set, a call to `getAsciiStream` returns meaningless information.

When you get `LONG` data with `getUnicodeStream`, you get a stream of Unicode characters in the `UTF-16` encoding. This applies to all underlying database character sets that Oracle supports.

When you get `LONG` data with `getBinaryStream`, there are two possible cases:

- If the driver is JDBC OCI and the *client* character set is *not* `US7ASCII` or `WE8ISO8859P1`, then a call to `getBinaryStream` returns `UTF-8`. If the *client* character set is `US7ASCII` or `WE8ISO8859P1`, then the call returns a `US7ASCII` stream of bytes.
- If the driver is JDBC Thin and the *database* character set is *not* `US7ASCII` or `WE8ISO8859P1`, then a call to `getBinaryStream` returns `UTF-8`. If the server-side character set is `US7ASCII` or `WE8ISO8859P1`, then the call returns a `US7ASCII` stream of bytes.

> **Note**
>
> Receiving `LONG` or `LONG RAW` columns as a stream requires you to pay special attention to the order in which you retrieve columns from the database.

The following table summarizes `LONG` and `LONG RAW` data conversions for each stream type.

Table 13-1 LONG and LONG RAW Data Conversions

Data type	BinaryStream	AsciiStream	UnicodeStream
LONG	Bytes representing characters in Unicode `UTF-8`. The bytes can represent characters in `US7ASCII` or `WE8ISO8859P1` if the database character set is `US7ASCII` or `WE8ISO8859P1`.	Bytes representing characters in ISO-Latin-1 (`WE8ISO8859P1`) encoding	Bytes representing characters in Unicode `UTF-16` encoding
LONG RAW	unchanged data	ASCII representation of hexadecimal bytes	Unicode representation of hexadecimal bytes

Related Topics

- Globalization Support
- Relation Between Data Streaming and Multiple Columns

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13.2.4 Examples:Streaming LONG RAW Data

One of the features of a `getXXXStream` method is that it enables you to fetch data incrementally. In contrast, `getBytes` fetches all the data in one call. This section contains two examples of getting a stream of binary data. The first version uses the `getBinaryStream` method to obtain `LONG RAW` data, and the second version uses the `getBytes` method.

Getting a LONG RAW Data Column with getBinaryStream

This example writes the contents of a `LONG RAW` column to a file on the local file system. In this case, the driver fetches the data incrementally.

The following code creates the table that stores a column of `LONG RAW` data associated with the name LESLIE:

```
-- SQL code:
create table streamexample (NAME varchar2 (256), GIFDATA long raw);
insert into streamexample values ('LESLIE', '0001020304050607080');
```

The following Java code snippet writes the data from the `LONG RAW` column into a file called `leslie.gif`:

```
ResultSet rset = stmt.executeQuery
                 ("select GIFDATA from streamexample where NAME='LESLIE'");

// get first row
if (rset.next())
{
    // Get the GIF data as a stream from Oracle to the client
    InputStream gif_data = rset.getBinaryStream (1);
   try
   {
      FileOutputStream file = null;
      file = new FileOutputStream ("leslie.gif");
      int chunk;
      while ((chunk = gif_data.read()) != -1)
         file.write(chunk);
   }
   catch (Exception e)
   {
      String err = e.toString();
      System.out.println(err);
   }
   finally
   {
      if file != null()
         file.close();
   }
}
```

In this example, the `InputStream` object returned by the call to `getBinaryStream` reads the data directly from the database connection.

Getting a LONG RAW Data Column with getBytes

This example gets the content of the `GIFDATA` column with `getBytes` instead of `getBinaryStream`. In this case, the driver fetches all the data in one call and stores it in a byte array. The code snippet is as follows:

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```
ResultSet rset2 = stmt.executeQuery
                  ("select GIFDATA from streamexample where NAME='LESLIE'");

// get first row
if (rset2.next())
{
   // Get the GIF data as a stream from Oracle to the client
   byte[] bytes = rset2.getBytes(1);
   try
   {
      FileOutputStream file = null;
      file = new FileOutputStream ("leslie2.gif");
      file.write(bytes);
   }
   catch (Exception e)
   {
      String err = e.toString();
      System.out.println(err);
   }
   finally
   {
      if file != null()
         file.close();
   }
}
```

Because a `LONG RAW` column can contain up to 2 gigabytes of data, the `getBytes` example can use much more memory than the `getBinaryStream` example. Use streams if you do not know the maximum size of the data in your `LONG` or `LONG RAW` columns.

13.2.5 About Avoiding Streaming for LONG or LONG RAW

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), this method is deprecated.

The JDBC driver automatically streams any `LONG` and `LONG RAW` columns. However, there may be situations where you want to avoid data streaming. For example, if you have a very small `LONG` column, then you may want to avoid returning the data incrementally and, instead, return the data in one call.

To avoid streaming, use the `defineColumnType` method to redefine the type of the `LONG` column. For example, if you redefine the `LONG` or `LONG RAW` column as `VARCHAR` or `VARBINARY` type, then the driver will not automatically stream the data.

If you redefine column types with `defineColumnType`, then you must declare the types of the columns in the query. If you do not declare the types of the columns, then `executeQuery` will fail. In addition, you must cast the `Statement` object to `oracle.jdbc.OracleStatement`.

As an added benefit, using `defineColumnType` saves the OCI driver a database round-trip when running the query. Without `defineColumnType`, these JDBC drivers must request the data types of the column types. The JDBC Thin driver derives no benefit from `defineColumnType`, because it always uses the minimum number of round-trips.

Using the example from the previous section, the `Statement` object `stmt` is cast to `OracleStatement` and the column containing `LONG RAW` data is redefined to be of the type

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VARBINARAY. The data is not streamed. Instead, it is returned in a byte array. The code snippet is as follows:

```
//cast the statement stmt to an OracleStatement
oracle.jdbc.OracleStatement ostmt =
   (oracle.jdbc.OracleStatement)stmt;

//redefine the LONG column at index position 1 to VARBINARY
ostmt.defineColumnType(1, Types.VARBINARY);

// Do a query to get the images named 'LESLIE'
ResultSet rset = ostmt.executeQuery
         ("select GIFDATA from streamexample where NAME='LESLIE'");

// The data is not streamed here
rset.next();
byte [] bytes = rset.getBytes(1);
```

13.3 About Streaming CHAR, VARCHAR, or RAW Columns

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), this method is deprecated..

If you use the `defineColumnType` Oracle extension to redefine a `CHAR`, `VARCHAR`, or `RAW` column as a `LONGVARCHAR` or `LONGVARBINARY`, then you can get the column as a stream. The program will behave as if the column were actually of type `LONG` or `LONG RAW`. Note that there is not much point to this, because these columns are usually short.

If you try to get a `CHAR`, `VARCHAR`, or `RAW` column as a data stream without redefining the column type, then the JDBC driver will return a Java `InputStream`, but no real streaming occurs. In the case of these data types, the JDBC driver fully fetches the data into an in-memory buffer during a call to the `executeQuery` method or the `next` method. The `get`*`XXX`*`Stream` entry points return a stream that reads data from this buffer.

13.4 About Streaming LOBs and External Files

The term large object (LOB) refers to a data item that is too large to be stored directly in a database table. Instead, a locator is stored in the database table, which points to the location of the actual data. External files are managed similarly. The JDBC drivers can support the following types through the use of streams:

- Binary large object (BLOB)

  For unstructured binary data
- Character large object (CLOB)

  For character data
- National Character large object (NCLOB)

  For national character data
- Binary file (BFILE)

  For external files

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LOBs and BFILEs behave differently from the other types of streaming data described in this chapter. Instead of storing the actual data in the table, a locator is stored. The actual data can be manipulated using this locator, including reading and writing the data as a stream. Even when streaming, only the chunk of data (defined by a size) is streamed across the network. By contrast, when streaming a `LONG` or `LONG RAW`, the entire data is streamed across the network.

Streaming BLOBs, CLOBs, and NCLOBs

When a query fetches one or more `BLOB`, `CLOB`, or `NCLOB` columns, the JDBC driver transfers the data to the client. This data can be accessed as a stream. To manipulate `BLOB`, `CLOB`, or `NCLOB` data from JDBC, use methods in the Oracle extension classes `oracle.sql.BLOB`, `oracle.sql.CLOB` and `oracle.sql.NCLOB`. These classes provide specific functionality, such as reading from the `BLOB`, `CLOB`, or `NCLOB` into an input stream, writing from an output stream into a `BLOB`, `CLOB`, or `NCLOB`, determining the length of a `BLOB`, `CLOB`, or `NCLOB`, and closing a `BLOB`, `CLOB`, or `NCLOB`.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the concrete classes in the `oracle.sql` package are deprecated and replaced with the interfaces in the `oracle.jdbc` package. Oracle recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about these interfaces.

> **See Also**
>
> "Data Interface for LOBs"

Streaming BFILEs

An external file, or BFILE, is used to store a locator to a file outside the database. The file can be stored somewhere on the file system of the data server. The locator points to the actual location of the file.

When a query fetches one or more `BFILE` columns, the JDBC driver transfers the file to the client as required. The data can be accessed as a stream To manipulate BFILE data from JDBC, use methods in the Oracle extension class `oracle.sql.BFILE`. This class provides specific functionality, such as reading from the BFILE into an input stream, writing from an output stream into a BFILE, determining the length of a BFILE, and closing a BFILE.

13.5 Relation Between Data Streaming and Multiple Columns

If a query fetches multiple columns and one of the columns contains a data stream, then the contents of the columns following the stream column are not available until the stream has been read, and the stream column is no longer available once any following column is read. Any attempt to read a column beyond a streaming column closes the streaming column.

Streaming Example with Multiple Columns

Consider the following code:

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```
ResultSet rset = stmt.executeQuery
        ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");
while rset.next()
{
   //get the date data
   java.sql.Date date = rset.getDate(1);

   // get the streaming data
   InputStream is = rset.getAsciiStream(2);

   // Open a file to store the gif data
   FileOutputStream file = new FileOutputStream ("ascii.dat");

   // Loop, reading from the ascii stream and
   // write to the file
   int chunk;
   while ((chunk = is.read ()) != -1)
      file.write(chunk);
   // Close the file
   file.close();

   //get the number column data
   int n = rset.getInt(3);
}
```

The incoming data for each row has the following shape:

```
<a date><the characters of the long column><a number>
```

As you process each row of the result set, you must complete any processing of the stream column before reading the number column.

Bypassing Streaming Data Columns

There may be situations where you want to avoid reading a column that contains streaming data. If you do not want to read such data, then call the `close` method of the stream object. This method discards the stream data and enables the driver to continue reading data from all the columns that contain non-streaming data and follow the column containing streaming data. Even though you are intentionally discarding the stream, it is a good programming practice to retrieve the columns in the same order as in the `SELECT` statement.

In the following example, the stream data in the `LONG` column is discarded and the data from only the `DATE` and `NUMBER` column is recovered:

```
ResultSet rset = stmt.executeQuery
        ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");

while rset.next()
{
   //get the date
   java.sql.Date date = rset.getDate(1);

   // access the stream data and discard it with close()
   InputStream is = rset.getAsciiStream(2);
   is.close();

   // get the number column data
   int n = rset.getInt(3);
}
```


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Related Topics

- About Streaming Data Precautions
- About Streaming LOBs and External Files

13.6 Closing a Stream

You can discard the data from a stream at any time by calling the `close` method. It is a good programming practice to close the stream when you no longer need it. For example:

```
...
InputStream is = rset.getAsciiStream(2);
is.close();
```

> **Note**
>
> Closing a stream has little performance effect on a LONG or LONG RAW column. All of the data still move across the network and the driver must read the bits from the network.

Related Topics

- Relation Between Data Streaming and Multiple Columns
- About Streaming Data Precautions

13.7 Notes and Precautions on Streams

This section discusses several cautionary issues regarding the use of streams:

- About Streaming Data Precautions
- About Using Streams to Avoid Limits on setBytes and setString
- Relation Between Streaming and Row Prefetching

13.7.1 About Streaming Data Precautions

This section describes some of the precautions you must take to ensure that you do not accidentally discard or lose your stream data. The drivers automatically discard stream data if you perform any JDBC operation that communicates with the database, other than reading the current stream. Two common precautions are:

- Use the stream data after you access it.

  To recover the data from a column containing a data stream, it is not enough to fetch the column. You must immediately process the contents of the column. Otherwise, the contents will be discarded when you fetch the next column.

- Call the stream column in the same order as in the `SELECT` statement.

  If your query fetches multiple columns, the database sends each row as a set of bytes representing the columns in the `SELECT` order. If one of the columns contains stream data, then the database sends the entire data stream before proceeding to the next column.

  If you do not use the order as in the `SELECT` statement to access data, then you can lose the stream data. That is, if you bypass the stream data column and access data in a

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column that follows it, then the stream data will be lost. For example, if you try to access the data for the `NUMBER` column *before* reading the data from the stream data column, then the JDBC driver first reads then discards the streaming data automatically. This can be very inefficient if the `LONG` column contains a large amount of data.

If you try to access the `LONG` column later in the program, then the data will not be available and the driver will return a "`Stream Closed`" error.

The later point is illustrated in the following example:

```
ResultSet rset = stmt.executeQuery
        ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");
while rset.next()
{
   int n = rset.getInt(3);  // This discards the streaming data
   InputStream is = rset.getAsciiStream(2);
                            // Raises an error: stream closed.
}
```

If you get the stream but do not use it *before* you get the `NUMBER` column, then the stream still closes automatically:

```
ResultSet rset = stmt.executeQuery
                 ("select DATECOL, LONGCOL, NUMBERCOL from TABLE");
while rset.next()
{
   InputStream is = rset.getAsciiStream(2); // Get the stream
   int n = rset.getInt(3);
   // Discards streaming data and closes the stream
}
int c = is.read(); // c is -1: no more characters to read-stream closed
```

13.7.2 About Using Streams to Avoid Limits on setBytes and setString

Starting from Oracle Database 12*c*, the size limit of the data that is used with the `setBytes` and `setString` methods, have been increased significantly. Any Java `byte` array can be passed to `setBytes`, and any Java `String` can be passed to `setString`. The JDBC driver automatically switches to using `setBinaryStream` or `setCharacterStream` or to using `setBytesForBlob` or `setStringForClob`, depending on the size of the data, whether the statement is SQL or PL/SQL, and the driver used.

There are some limitation with earlier versions of Oracle Database and in the server-side internal driver.

Related Topics

- Data Interface for LOBs
  The data interface for LOBs includes a set of Java and OCI APIs that are extended to work with LOB data types.

13.7.3 Relation Between Streaming and Row Prefetching

If the JDBC driver encounters a column containing a data stream, then row fetch size is set back to one. Row fetch size is an Oracle performance enhancement that enables multiple rows of data to be retrieved with each trip to the database.

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14

Working with Vectors

Starting with Oracle Database Release 23ai, you can declare a table's column as a Vector. A Vector is an array of one or more numeric values that may be integers or fractional numbers.

You can use the Vector data for machine learning. Oracle AI (Artificial Intelligence) Vector Search enables you to query data based on semantics, rather than keywords. For more information about Oracle AI Vector Search, refer to the *Oracle AI Vector Search User's Guide*.

- JDBC APIs and Types for Vectors
- SQL to Java Conversions with CallableStatement
- SQL to Java Conversions with CallableStatment and ResultSet
- Java to SQL Conversions with PreparedStatement and CallableStatement
- The VECTOR Datum Class
- Backward Compatibility with Earlier JDBC Drivers

14.1 JDBC APIs and Types for Vectors

JDBC drivers represent SQL data types as instances of the `java.sql.SQLType` interface. For each data type of Oracle Database, the Oracle JDBC Driver declares an instance of `SQLType` as a member of `oracle.jdbc.OracleType`.

14.1.1 JDBC Types for Vectors

This section describes the new instances of SQLType that are added to the `oracle.jdbc.OracleType` enum for Vector support. These instances represent the VECTOR data type.

> **Note**
>
> Java object types that can be converted to and from the VECTOR data type are specified in the Java API Reference documentation of each type.

VECTOR
`OracleType.VECTOR` represents a Vector of any type, that is, a type with an asterisk (*) wild card.

VECTOR_INT8
`OracleType.VECTOR_INT8` represents a Vector of `INT8` values.

VECTOR_FLOAT32
`OracleType.VECTOR_FLOAT32` represents a Vector of `FLOAT32` values.

VECTOR_FLOAT64
`OracleType.VECTOR_FLOAT64` represents a Vector of `FLOAT64` values.

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You *must* use these type codes when a `PreparedStatement` has a Vector type parameter. You can provide this type as an argument to the `setObject(int, Object, SQLType)` method or the `setObject(int, Object, int)` method. A Vector parameter *cannot* be set by calling the `setObject(int, Object)` method.

14.1.2 JDBC Interfaces for Vectors

This section describes the JDBC interfaces that have been added or updated for Vector support.

14.1.2.1 The VectorMetaData Interface

The new interface, `oracle.jdbc.VectorMetaData` stores the metadata for a Vector column or parameter.

14.1.2.2 The DatabaseMetaData Interface

JDBC drivers represent metadata of tables and stored procedures as instances of the `java.sql.DatabaseMetaData` interface.

> **See Also**
>
> The Java SE Documentation

14.1.2.3 The OracleResultSetMetaData and OracleParameterMetaData Interfaces

JDBC drivers represent metadata of columns and parameters as instances of the `java.sql.ResultSetMetaData` and `java.sql.ParameterMetaData` interfaces respectively. The Oracle JDBC Driver extends the `ResultSetMetaData` and `ParameterMetaData` interfaces with `OracleResultSetMetaData` and `OracleParameterMetaData` interfaces, respectively.

14.1.2.4 The SparseArray Interface

Sparse vectors are vectors that typically have a large number of dimensions but with very few non-zero dimension values. For JDBC applications, conversion must happen between the Java objects and the sparse vectors. As Java has no built-in object to represent sparse data, the `SparseArray` interface is used for this purpose.

> **See Also**
>
> - *Oracle AI Vector Search User's Guide*
> - Oracle Database JDBC Java API Reference

The `SparseArray` interface contains the following sub-interfaces that use a certain Java numeric type to store non-zero values like `double`, `float`, `byte`, and `boolean`:

- `SparseDoubleArray`
- `SparseFloatArray`
- `SparseArray`

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- `SparseDoubleArray`

You can use these sub-interfaces as bind values for the `PreparedStatement.setObject(int, Object)` method and as return values for the `ResultSet.getObject(int, Class)` method.

14.1.3 JDBC Methods for Vectors

This section describes the JDBC methods that have been added or updated for Vector support. It also describes the behavior of standard JDBC methods with respect to Vector data.

The getVectorMetaData Method

A method named `getVectorMetaData` is added to the `OracleResultSetMetaData` and `OracleParameterMetaData` interfaces. The method returns an instance of the `oracle.jdbc.VectorMetaData` interface for a Vector column or parameter, which enables the applications to identify the size and the type of the Vector data at run time. The method returns `null` for a column or parameter that is not a Vector.

The getLength Method

A method named `getLength` returns the number of values in a Vector column or parameter. For example:

- The method returns 3 for a column declared as VECTOR(3, `INT8`).
- The method returns -1 for a Vector column or parameter with a variable length, that is, where asterisk (*) is specified as the length. For example, VECTOR(`*`, `INT8`).

The getArrayClass Method

A method named `getArrayClass` returns the class of an array object, which you can use in conversions of a Vector column or parameter. For example,

- `double[].class` is returned for a column or parameter that is a Vector of any type. For example, VECTOR(`*`, `*`)
- `byte[].class` is returned for a column or parameter that is a Vector of `INT8` values.
- `float[].class` is returned for a column or parameter that is a Vector of `FLOAT32` values.
- `double[].class` is returned for a column or parameter that is a Vector of `FLOAT64` values.

The getType Method

The `getType` method returns one of the following `OracleTypes` for a Vector column or parameter:

- `OracleTypes.VECTOR` is returned for a column or parameter that is a Vector of any type, that is, a VECTOR(<*length*>,*) type
- `OracleTypes.VECTOR_INT8` is returned for a column or parameter that is a Vector of `INT8` values.
- `OracleTypes.VECTOR_FLOAT32` is returned for a column or parameter that is a Vector of `FLOAT32` values.
- `OracleTypes.VECTOR_FLOAT64` is returned for a column or parameter that is a Vector of `FLOAT64` values.

The getColumns Method

The `getColumns` method retrieves Vector columns in the following ways:

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- The `getColumns` method returns the `int` value of `oracle.jdbc.OracleTypes.VECTOR (-105)` as the `DATA_TYPE` for a Vector column.
- The `getColumns` method returns the String value of `"VECTOR"` as the `TYPE_NAME` for a Vector column.

The getObject(int) or getObject(String) Methods

When you call the `getObject(int)` or `getObject(String)` methods of the `java.sql.ResultSet` interface, there is no default mapping for the VECTOR data type. But, you can choose a default mapping with the `oracle.jdbc.vectorDefaultGetObjectType` connection property.

The getPrecision and getScale Methods

The `getPrecision` and `getScale` methods return 0 for a Vector column or parameter. The JDBC 4.3 Specification does not define the correct behavior of these methods for the VECTOR data type. The return values of 0 indicate that precision and scale are not applicable to the data type. All other methods behave as specified by the JDBC 4.3 Specification.

14.2 SQL to Java Conversions with CallableStatement

JDBC drivers represent procedural SQL calls as instances of the `java.sql.CallableStatement` interface. The interface defines the `registerOutParameter` methods that specify the SQL type of an `out` parameter. A corresponding `getObject` method is defined, which converts the registered SQL type to a Java object.

> **See Also**
>
> The CallableStatement Interface

This section specifies the conversions of the `getObject` method, when converting a Vector to a Java object.

> **Note**
>
> This section does *not* specify the behavior of the `getObject` methods that accept a `Class` argument. The behavior of these methods is specified in the SQL to Java Conversions with CallableStatment and ResultSet section. These methods are not influenced by a SQL type registered with the registerOutParameter method.

This section discusses the behavior of the *widening* and *narrowing* conversions that are possible with Vectors:

> **See Also**
>
> - Widening Primitive Conversion
> - Narrowing Primitive Conversion

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OracleType.VECTOR Registrations

The `registerOutParameter` methods recognize `OracleType.VECTOR` and `OracleTypes.VECTOR`. With this registration, the following conversions are performed by the `getObject` methods, if no `Class` argument is provided:

- A Vector of `INT8` values is converted to a `byte[]`
- A Vector of `FLOAT32` values is converted to a `float[]`
- A Vector of `FLOAT64` values is converted to a `double[]`

OracleType.VECTOR_INT8 Registrations

The `registerOutParameter` methods recognize `OracleType.VECTOR_INT8` and `OracleTypes.VECTOR_INT8`. With this registration, the following conversions are performed by the `getObject` methods, if no `Class` argument is provided:

- A Vector of `INT8` values is converted to a `byte[]`. No additional conversion occurs in this case.
- A Vector of `FLOAT32` values is converted to a `byte[]`, where, a widening conversion of `byte` to `float` occurs.

OracleType.VECTOR_FLOAT32 Registrations

The `registerOutParameter` methods recognize `OracleType.VECTOR_FLOAT32` and `OracleTypes.VECTOR_FLOAT31`. With this registration, the following conversions are performed by the `getObject` methods, if no Class argument is provided:

- A Vector of `INT8` values is converted to a `float[]`, where, a widening conversion of `byte` to `float` occurs.
- A Vector of `FLOAT32` values is converted to a `float[]`. No additional conversion occurs in this case.
- A Vector of `FLOAT64` values is converted to a `float[]`, where, a narrowing conversion of `double` to `float` occurs.

OracleType.VECTOR_FLOAT64 Registrations

The `registerOutParameter` methods recognize `OracleType.VECTOR_FLOAT64` and `OracleTypes.VECTOR_FLOAT64`. With this registration, the following conversions are performed by the `getObject` methods, if no `Class` argument is provided:

- A Vector of `INT8` values is converted to a `double[]`, where, a widening conversion of `byte` to `double` occurs.
- A Vector of `FLOAT32` values is converted to a `double[]`, where, a widening conversion of `float` to `double` occurs.
- A Vector of `FLOAT64` values is converted to a `double[]`. No additional conversion occurs in this case.

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14.3 SQL to Java Conversions with CallableStatment and ResultSet

JDBC drivers represent the values of out parameters and columns as instances of the `java.sql.CallableStatement` and `java.sql.ResultSet` interfaces respectively. Both the interfaces define `getObject` methods that convert a SQL type to a Java object.

This section describes the behavior of the `getObject` methods, when converting Vector parameters and columns to Java objects.

This section discusses the behavior of the *widening* and *narrowing* conversions that are possible with Vectors:

See Also

- Widening Primitive Conversion
- Narrowing Primitive Conversion

Default Conversions

The `getObject(int)` and `getObject(String)` methods of the `ResultSet` interface do *not* support conversions of Vector columns. The JDBC 4.3 Specification does not specify any class of Java object as the default conversion of Vector.

The `getObject(int)` and `getObject(String)` methods of the `CallableStatement` interface support conversions of Vector columns. Refer to the SQL to Java Conversions with CallableStatement section for more details.

boolean[] Conversions

The `getObject` methods recognize `boolean[].class` as a target Java type. The following conversions are performed:

- A Vector of `INT8` values is converted to `boolean[]`. A value of 0 is converted to `false`, and a value that is not 0, is converted to `true`.
- A Vector of `FLOAT32` values is converted to `boolean[]`. A value of 0.0 is converted to `false`, and a value that is not 0.0, is converted to `true`.
- A Vector of `FLOAT64` values is converted to `boolean[]`. A value of 0.0 is converted to `false`, and a value that is not 0.0, is converted to `true`.

byte[] Conversions

The `getObject` methods recognize `byte[].class` as a target Java type. The following conversions are performed:

- A Vector of `INT8` values is converted to `byte[]`. No additional conversion is performed in this case.
- A Vector of `FLOAT32` values is converted to `byte[]`, where, a narrowing conversion of `float` to `byte` occurs.
- A Vector of `FLOAT64` values is converted to `byte[]`, where, a narrowing conversion of `double` to `byte` occurs.

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short[] Conversions

The `getObject` methods recognize `short[].class` as a target Java type. The following conversions are performed:

- A Vector of `INT8` values is converted to `short[]`, where, a widening conversion of `byte` to `short` occurs.
- A Vector of `FLOAT32` values is converted to `short[]`, where, a narrowing conversion of `float` to `short` occurs.
- A Vector of `FLOAT64` values is converted to `short[]`, where, a narrowing conversion of `double` to `short` occurs.

int[] Conversions

The `getObject` methods recognize `int[].class` as a target Java type. The following conversions are performed:

- A Vector of `INT8` values is converted to `int[]`, where, a widening conversion of `byte` to `int` occurs.
- A Vector of `FLOAT32` values is converted to `int[]`, where, a narrowing conversion of `float` to `int` occurs.
- A Vector of `FLOAT64` values is converted to `byte[]`, where, a narrowing conversion of `double` to `int` occurs.

long[] Conversions

The `getObject` methods recognize `long[].class` as a target Java type. The following conversions are performed:

- A Vector of `INT8` values is converted to `long[]`, where, a widening conversion of `byte` to `long` occurs.
- A Vector of `FLOAT32` values is converted to `long[]`, where, a narrowing conversion of `float` to `long` occurs.
- A Vector of `FLOAT64` values is converted to `long[]`, where, a narrowing conversion of `double` to `long` occurs.

float[] Conversions

The `getObject` methods recognize `float[].class` as a target Java type. The following conversions are performed:

- A Vector of `INT8` values is converted to `float[]`, where, a widening conversion of `byte` to `int` occurs.
- A Vector of `FLOAT32` values is converted to `float[]`. No additional conversion is performed in this case.
- A Vector of `FLOAT64` values is converted to `float[]`, where, a narrowing conversion of `double` to `float` occurs.

double[] Conversions

The `getObject` methods recognize `double[].class` as a target Java type. The following conversions are performed:

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- A Vector of `INT8` values is converted to `double[]`, where, a widening conversion of`byte` to `double` occurs.
- A Vector of `FLOAT32` values is converted to `double[]`, where, a widening conversion of`float` to `double` occurs.
- A Vector of `FLOAT64` values is converted to `double[]`, where, a narrowing conversion of `double` to `float` occurs.

14.4 Java to SQL Conversions with PreparedStatement and CallableStatement

JDBC drivers represent SQL commands as instances of the `java.sql.PreparedStatement` and `java.sql.CallableStatement` interfaces. These interfaces define the `setObject` methods that convert a Java object to a SQL type. This section describes the behavior of the `setObject` method, when converting Java objects to a Vector.

See Also

- The PreparedStatement Interface
- The CallableStatement Interface

This section discusses the behavior of the *widening* and *narrowing* conversions that are possible with Vectors:

See Also

- Widening Primitive Conversion
- Narrowing Primitive Conversion

Default Conversion

The `setObject(int, Object)` method does not support conversions to Vectors. The JDBC 4.3 Specification does not specify Vector as the default conversion for any class of Java object.

OracleType.VECTOR Conversions

The `setObject` methods recognize `OracleType.VECTOR` and `OracleTypes.VECTOR` as a target SQL type. The following conversions are supported for this type:

- A `byte[]` is converted to a Vector of `INT8` values
- A `float[]` is converted to a Vector of `FLOAT32` values
- A `double[]` is converted to a Vector of `FLOAT64` values.

OracleType.VECTOR_INT8 Conversions

The `setObject` methods recognize `OracleType.VECTOR_INT8` and `OracleTypes.VECTOR_INT8` as a target SQL type. The following conversions are supported for this target SQL type:

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- A `boolean[]` is converted to a Vector of `INT8` values. A boolean value of `false` is converted to 0, and a value of `true` is converted to 1.
- A `byte[]` is converted to a Vector of `INT8` values. No additional conversion occurs in this case.
- A `short[]` is converted to a Vector of `INT8` values, where, a narrowing conversion of `short` to `byte` occurs.
- An `int[]` is converted to a Vector of `INT8` values, where, a narrowing conversion of `int` to `byte` occurs.
- A `long[]` is converted to a Vector of `INT8` values, where, a narrowing conversion of `long` to `byte` occurs.
- A `float[]` is converted to a Vector of `INT8` values, where, a narrowing conversion of `float` to `byte` occurs.
- A `double[]` is converted to a Vector of `INT8` values, where, a narrowing conversion of `double` to `byte` occurs.

OracleType.VECTOR_FLOAT32 Conversions

The `setObject` methods recognize `OracleType.VECTOR_FLOAT32` and `OracleTypes.VECTOR_FLOAT32` as a target SQL type. The following conversions are supported for this target SQL type:

- A `boolean[]` is converted to a Vector of `FLOAT32` values. A boolean value of `false` is converted to 0.0, and a value of `true` is converted to 1.0.
- A `byte[]` is converted to a Vector of `FLOAT32` values, where, a widening conversion of `byte` to `float` occurs.
- A `short[]` is converted to a Vector of `FLOAT32` values, where, a widening conversion of `short` to `float` occurs.
- An `int[]` is converted to a Vector of `FLOAT32` values, where, a widening conversion of `int` to `float` occurs.
- A `long[]` is converted to a Vector of `FLOAT32` values, where, a widening conversion of `long` to `float` occurs.
- A `float[]` is converted to a Vector of `FLOAT32` values. No additional conversion occurs in this case.
- A `double[]` is converted to a Vector of `FLOAT32` values, where, a narrowing conversion of `double` to `float` occurs.

OracleType.VECTOR_FLOAT64 Conversions

The `setObject` methods recognize `OracleType.VECTOR_FLOAT64` and `OracleTypes.VECTOR_FLOAT64` as a target SQL type. The following conversions are supported for this target SQL type:

- A `boolean[]` is converted to a Vector of `FLOAT64` values, where, a boolean value of `false` is converted to 0.0 and `true` is converted to 1.0.
- A `byte[]` is converted to a Vector of `FLOAT64` values, where, a widening conversion of `byte` to `double` occurs.
- A `short[]` is converted to a Vector of `FLOAT64` values, where, a widening conversion of `short` to `double` occurs.

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- An `int[]` is converted to a Vector of `FLOAT64` values, where, a widening conversion of `int` to `double` occurs.
- A `long[]` is converted to a Vector of `FLOAT64` values, where, a widening conversion of `long` to `double` occurs.
- A `float[]` is converted to a Vector of `FLOAT64` values, where, a widening conversion of `float` to `double` occurs.
- A `double[]` is converted to a Vector of `FLOAT64` values. No additional conversion occurs in this case.

14.5 The VECTOR Datum Class

The `oracle.sql` package defines a `Datum` class with subclasses that represent each Oracle SQL data type. For example, the `oracle.sql.NUMBER` subclass represents a value of the `NUMBER` data type, and `oracle.sql.TIMESTAMP` represents values of the `TIMESTAMP` data type.

A new subclass `oracle.sql.VECTOR` is added to the `Datum` class to represent values of Vector columns. The `VECTOR` class supports conversions between Java objects and Oracle's binary encoding of a Vector.

Conversions from Java Objects

The `VECTOR` class defines factory methods that create an instance of a Vector. These factory methods convert a Java object into the binary encoding of a Vector in the following ways:

- An `ofFloat64Values(Object)` method converts a Java object into a Vector of `FLOAT64` values.
- An `ofFloat32Values(Object)` method converts a Java object into a Vector of `FLOAT32` values.
- An `ofInt8Values(Object)` method converts a Java object into a Vector of `INT8` values.

> **See Also**
>
> Java to SQL Conversions with PreparedStatement and CallableStatement

Conversions to Java Objects

The `VECTOR` class defines instance methods that return a Java object representation of a Vector. These instance methods convert the binary encoding of a Vector into a Java object in the following ways:

- The `toBooleanArray()` method converts a Vector into an array of `boolean` values
- The `toByteArray()` method converts a Vector into an array of `byte` values
- The `toShortArray()` method converts a Vector into an array of `short` values
- The `toIntArray()` method converts a Vector into an array of `int` values
- The `toLongArray()` method converts a Vector into an array of `long` values
- The `toFloatArray()` method converts a Vector into an array of `float` values
- The `toDoubleArray()` method converts a Vector into an array of `double` values

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> **See Also**
>
> SQL to Java Conversions with CallableStatment and ResultSet

14.6 Backward Compatibility with Earlier JDBC Drivers

Earlier releases of Oracle JDBC may connect to an Oracle Database 23ai. These JDBC builds do not have built-in support for the VECTOR data type, but they do support the `VARCHAR` and `CLOB` data types, and applications may use these types for DML and query operations on Vector columns.

JDBC supports conversions of `String` with `VARCHAR` and `java.sql.Clob` with `CLOB`. These conversions have consistent behavior in Oracle Database 19c, 21c, and 23ai releases.

The following code example demonstrates these conversions, where a `String` and `java.sql.Clob` are passed to the `PreparedStatement.setObject` method. Conversions of `CLOB` to `String` are demonstrated by calling the `ResultSet.getObject(int, Class)` method with the `String.class` method.

```
import oracle.jdbc.OracleStatement;

import java.sql.Clob;
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.ResultSetMetaData;
import java.sql.SQLException;
import java.sql.Statement;
import java.sql.Types;
import java.util.Arrays;
import java.util.Random;

/**
 * This example can be run with 19.x releases of Oracle JDBC. It uses String
to
 * represent VECTOR data, which may be suitable for database tools.
 */
public class VectorStringTest {

  public static void main(String[] args) throws SQLException {

    try (
      Connection connection =
        DriverManager.getConnection("jdbc:oracle:thin:@test");
      Table table = new Table(connection);
      PreparedStatement insert = connection.prepareStatement(
        "INSERT INTO vector_test(id, value) VALUES (?, ?)");
      PreparedStatement query = connection.prepareStatement(
        "SELECT id, value FROM vector_test ORDER BY id")) {

      // Toy example to show the VARCHAR literal syntax of a VECTOR: A comma
      // separated numbers enclosed in square brackets.
      String vectorLiteral = "[0.1, 0.2, 0.3]";
```


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```
      insert.setString(1, "0");
      insert.setString(2, vectorLiteral);
      System.out.println("Inserting VECTOR (VARCHAR):\n\t" + vectorLiteral);
      insert.executeUpdate();

      // Generate a Vector of 256 dimensions, each having many decimal point
      // digits. Arrays.toString(double[]) conveniently generates the Vector
      // literal syntax, so it may be used to convert the Vector to String.
      double[] vector = getVector(256);
      String vectorString = Arrays.toString(vector);
      insert.setObject(1, "1");
      insert.setObject(2, vectorString);
      System.out.println("Inserting VECTOR (VARCHAR):\n\t" + vectorString);
      insert.executeUpdate();

      // If the String is longer than 32k characters, then it must be
converted
      // to a CLOB (32k is the maximum length of a VARCHAR).
      // This example results in:
      //   ORA-42552: VECTOR() library processing error
'LVECTOR_ERR_INPUT_NAN_OR_INF' in 'qvcCons:lvector_from_oratext'.
      // The 2048 length is commented out for this reason. A 256 length is
used
      // just to demonstrate the conversion to CLOB.
      // double[] largeVector = getVector(2048);
      double[] largeVector = getVector(256);
      Clob vectorClob = connection.createClob();
      try {
        String largeVectorString = Arrays.toString(largeVector);
        vectorClob.setString(1L, largeVectorString);
        insert.setString(1, "2");
        insert.setObject(2, vectorClob);
        System.out.println("Inserting VECTOR (CLOB):\n\t" +
largeVectorString);
        insert.executeUpdate();
      }
      finally {
        vectorClob.free();
      }

      // Query the VECTOR column. For a 19c JDBC client, the database sends
the
      // VECTOR as a CLOB. For a 23ai JDBC client, it sends it as the VECTOR
binary
      // encoding. When the getString method has JDBC convert the VECTOR, both
      // client versions should return the same text value.
      try (ResultSet resultSet = query.executeQuery()) {
        ResultSetMetaData metaData = resultSet.getMetaData();
        while (resultSet.next()) {
          System.out.println("Queried VECTOR:");
          System.out.printf(
            "\t%s (%s) : %s%n",
            metaData.getColumnName(1),
            metaData.getColumnTypeName(1),
            resultSet.getString(1));
          System.out.printf(
```


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```
            "\t%s (%s) : %s%n",
            metaData.getColumnName(2),
            metaData.getColumnTypeName(2),
            resultSet.getString(2));
        }
      }

      // Applications can request that the database always sends the VECTOR
      // as a CLOB. The defineColumnType method is used to specify the CLOB
      // type.
      System.out.println("\nQuerying VECTOR as CLOB");
      query.unwrap(OracleStatement.class)
        .defineColumnType(2, Types.CLOB);
      try (ResultSet resultSet = query.executeQuery()) {
        ResultSetMetaData metaData = resultSet.getMetaData();
        while (resultSet.next()) {
          System.out.println("Queried VECTOR:");
          System.out.printf(
            "\t%s (%s) : %s%n",
            metaData.getColumnName(1),
            metaData.getColumnTypeName(1),
            resultSet.getString(1));
          System.out.printf(
            "\t%s (%s) : %s%n",
            metaData.getColumnName(2),
            metaData.getColumnTypeName(2),
            resultSet.getString(2));
        }
      }

    }
  }

  static double[] getVector(int length) {
    return new Random(0).doubles()
      .limit(length)
      .toArray();
  }

  static class Table implements AutoCloseable {

    private final Connection connection;

    Table(Connection connection) throws SQLException {
      try (Statement statement = connection.createStatement()) {
        statement.addBatch("DROP TABLE IF EXISTS vector_test");
        statement.addBatch(
          "CREATE TABLE vector_test" +
            " (id NUMBER PRIMARY KEY, value VECTOR(*,*))");
        statement.executeBatch();
      }
      this.connection = connection;
    }

    @Override
    public void close() throws SQLException {
```


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```
            try (Statement statement = connection.createStatement()) {
              statement.execute("DROP TABLE IF EXISTS vector_test");
            }
          }
        }
      }
```


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15

Working with Oracle Object Types

This chapter describes the Java Database Connectivity (JDBC) support for user-defined object types. It discusses functionality of the generic, weakly typed `oracle.sql.STRUCT` class, as well as how to map to custom Java classes that implement either the JDBC standard `SQLData` interface or the Oracle-specific `OracleData` interface.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.STRUCT` class is deprecated and replaced with the `oracle.jdbc.OracleStruct` interface, which is a part of the `oracle.jdbc` package. Oracle strongly recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleStruct` interface.

The following topics are covered:

- About Mapping Oracle Objects
- About Using the Default STRUCT Class for Oracle Objects
- About Creating and Using Custom Object Classes for Oracle Objects
- Object-Type Inheritance
- About Describing an Object Type

Related Topics

- About Using PL/SQL Types

15.1 About Mapping Oracle Objects

Oracle object types provide support for composite data structures in the database. For example, you can define a `Person` type that has the attributes `name` of `CHAR` type, `phoneNumber` of `CHAR` type, and `employeeNumber` of `NUMBER` type.

Oracle provides tight integration between its Oracle object features and its JDBC functionality. You can use a standard, generic JDBC type to map to Oracle objects, or you can customize the mapping by creating custom Java type definition classes.

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> **Note**
>
> In this book, Java classes that you create to map to Oracle objects will be referred to as **custom Java classes** or, more specifically, **custom object classes**. This is as opposed to **custom references classes**, which are Java classes that map to object references, and **custom collection classes**, which are Java classes that map to Oracle collections.

Custom object classes can implement either a standard JDBC interface or an Oracle extension interface to read and write data. JDBC materializes Oracle objects as instances of particular Java classes. Two main steps in using JDBC to access Oracle objects are:

1. Creating the Java classes for the Oracle objects
2. Populating these classes. You have the following options:
   - Let JDBC materialize the object as a `STRUCT` object.
   - Explicitly specify the mappings between Oracle objects and Java classes.

     This includes customizing your Java classes for object data. The driver then must be able to populate instances of the custom object classes that you specify. This imposes a set of constraints on the Java classes. To satisfy these constraints, you can define your classes to implement either the JDBC standard `java.sql.SQLData` interface or the Oracle extension `oracle.jdbc.OracleData` interface.

> **Note**
>
> When you use the `SQLData` interface, you must use a Java type map to specify your SQL-Java mapping, unless weakly typed `java.sql.Struct` objects will suffice.

15.2 About Using the Default STRUCT Class for Oracle Objects

This section covers the following topics:

- Overview of Using the Struct Class
- Retrieving STRUCT Objects and Attributes
- About Creating STRUCT Objects
- Binding STRUCT Objects into Statements
- STRUCT Automatic Attribute Buffering

15.2.1 Overview of Using the Struct Class

If you choose not to supply a custom Java class for your SQL-Java mapping for an Oracle object, then Oracle JDBC materializes the object as an object that implements the `java.sql.Struct` interface.

You would typically want to use `STRUCT` objects, instead of custom Java objects, in situations where you do not know the actual SQL type. For example, your Java application might be a tool to manipulate arbitrary object data within the database, as opposed to being an end-user application. You can select data from the database into `STRUCT` objects and create `STRUCT`

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objects for inserting data into the database. STRUCT objects completely preserve data, because they maintain the data in SQL format. Using STRUCT objects is more efficient and more precise in situations where you do not need the information in an application specific form.

15.2.2 Retrieving STRUCT Objects and Attributes

This section discusses how to retrieve and manipulate Oracle objects and their attributes, using either Oracle-specific features or JDBC 2.0 standard features.

> **Note**
>
> The JDBC driver seamlessly handles embedded objects, that is, STRUCT objects that are attributes of STRUCT objects, in the same way that it typically handles objects. When the JDBC driver retrieves an attribute that is an object, it follows the same rules of conversion by using the type map, if it is available, or by using default mapping.

Retrieving an Oracle Object as a java.sql.Struct Object

Alternatively, in the preceding example, you can use standard JDBC functionality, such as `getObject`, to retrieve an Oracle object from the database as an instance of `java.sql.Struct`. The `getObject` method returns a `java.lang.Object`, so, you must cast the output of the method to `Struct`. For example:

```
ResultSet rs= stmt.executeQuery("SELECT * FROM struct_table");
java.sql.Struct jdbcStruct = (java.sql.Struct)rs.getObject(1);
```

Retrieving Attributes as oracle.sql Types

If you want to retrieve Oracle object attributes from a `STRUCT` or `Struct` instance as `oracle.sql` types, then use the `getOracleAttributes` method of the `oracle.sql.STRUCT` class, as follows:

```
oracle.sql.Datum[] attrs = oracleSTRUCT.getOracleAttributes();
```

or:

```
oracle.sql.Datum[] attrs = ((oracle.sql.STRUCT)jdbcStruct).getOracleAttributes();
```

Retrieving Attributes as Standard Java Types

If you want to retrieve Oracle object attributes as standard Java types from a `STRUCT` or `Struct` instance, use the standard `getAttributes` method:

```
Object[] attrs = jdbcStruct.getAttributes();
```

> **Note**
>
> Oracle JDBC drivers cache array and structure descriptors. This provides enormous performance benefits. However, it means that if you change the underlying type definition of a structure type in the database, the cached descriptor for that structure type will become stale and your application will receive a `SQLException` exception.

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15.2.3 About Creating STRUCT Objects

For information about creating STRUCT objects, refer to "Package oracle.sql".

> **Note**
>
> If you have already fetched from the database a `STRUCT` of the appropriate SQL object type, then the easiest way to get a `STRUCT` descriptor is to call `getDescriptor` on one of the fetched `STRUCT` objects. Only one `STRUCT` descriptor is needed for any one SQL object type.

15.2.4 Binding STRUCT Objects into Statements

To bind an `oracle.sql.STRUCT` object to a prepared statement or callable statement, you can either use the standard `setObject` method (specifying the type code), or cast the statement object to an Oracle statement type and use the Oracle extension `setOracleObject` method. For example:

```
PreparedStatement ps= conn.prepareStatement("text_of_prepared_statement");
Struct mySTRUCT = conn.createStruct (...);
ps.setObject(1, mySTRUCT, Types.STRUCT);
```

or:

```
PreparedStatement ps= conn.prepareStatement("text_of_prepared_statement");
Struct mySTRUCT = conn.createStruct (...);
((OraclePreparedStatement)ps).setOracleObject(1, mySTRUCT);
```

15.2.5 STRUCT Automatic Attribute Buffering

Oracle JDBC driver furnishes public methods to enable and disable buffering of `STRUCT` attributes.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.STRUCT` class is deprecated and replaced with the `oracle.jdbc.OracleStruct` interface, which is a part of the `oracle.jdbc` package. Oracle strongly recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleStruct` interface.

The following methods are included with the `oracle.sql.STRUCT` class:

- `public void setAutoBuffering(boolean enable)`
- `public boolean getAutoBuffering()`

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The `setAutoBuffering(boolean)` method enables or disables auto-buffering. The `getAutoBuffering` method returns the current auto-buffering mode. By default, auto-buffering is disabled.

It is advisable to enable auto-buffering in a JDBC application when the `STRUCT` attributes are accessed more than once by the `getAttributes` and `getArray` methods, presuming the `ARRAY` data is able to fit into the Java Virtual Machine (JVM) memory without overflow.

> **Note**
>
> Buffering the converted attributes may cause the JDBC application to consume a significant amount of memory.

When you enable auto-buffering, the `oracle.sql.STRUCT` object keeps a local copy of all the converted attributes. This data is retained so that subsequent access of this information does not require going through the data format conversion process.

Related Topics

- ARRAY Automatic Element Buffering

15.3 About Creating and Using Custom Object Classes for Oracle Objects

This section covers the following topics:

- Overview of Creating and Using Custom Object Classes
- Relative Advantages of OracleData versus SQLData
- About Type Maps for SQLData Implementations
- About Creating Type Map and Defining Mappings for a SQLData Implementation
- About Reading and Writing Data with a SQLData Implementation
- About the OracleData Interface
- About Reading and Writing Data with an OracleData Implementation
- Additional Uses of OracleData

15.3.1 Overview of Creating and Using Custom Object Classes

If you want to create custom object classes for your Oracle objects, then you must define entries in the type map that specify the custom object classes that the drivers instantiate for the corresponding Oracle objects.

You must also provide a way to create and populate instances of the custom object class from the Oracle object and its attribute data. The driver must be able to read from a custom object class and write to it. In addition, the custom object class can provide `get`*`XXX`* and `set`*`XXX`* methods corresponding to the attributes of the Oracle object, although this is not necessary. To create and populate the custom classes and provide these read/write capabilities, you can choose between the following interfaces:

- The JDBC standard `SQLData` interface

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- The `OracleData` and `OracleDataFactory` interfaces provided by Oracle

The custom object class you create must implement one of these interfaces. The `OracleData` interface can also be used to implement the custom reference class corresponding to the custom object class. However, if you are using the `SQLData` interface, then you can use only weak reference types in Java, such as `java.sql.Ref` or `oracle.sql.REF`. The `SQLData` interface is for mapping SQL objects only.

As an example, assume you have an Oracle object type, `EMPLOYEE`, in the database that consists of two attributes: `Name`, which is of the `CHAR` type and `EmpNum`, which is of the `NUMBER` type. You use the type map to specify that the `EMPLOYEE` object should map to a custom object class that you call `JEmployee`. You can implement either the `SQLData` or `OracleData` interface in the `JEmployee` class.

Related Topics

- Object-Type Inheritance

15.3.2 Relative Advantages of OracleData versus SQLData

In deciding which of the two interface implementations to use, you need to consider the advantages of `OracleData` and `SQLData`.

The `SQLData` interface is for mapping SQL objects only. The `OracleData` interface is more flexible, enabling you to map SQL objects as well as any other SQL type for which you want to customize processing. You can create an `OracleData` implementation from any data type found in Oracle Database. This could be useful, for example, for serializing `RAW` data in Java.

Advantages of the OracleData Interface

The advantages of the `OracleData` interface are:

- It does not require an entry in the type map for the Oracle object.
- It has awareness of Oracle extensions.
- You can construct an `OracleData` from an `oracle.sql.STRUCT`. This is more efficient because it avoids unnecessary conversions to native Java types.
- You can obtain the corresponding JDBC object from `OracleData`, using the `toJDBCObject` method.

Advantages of SQLData

`SQLData` is a JDBC standard that makes your code portable.

15.3.3 About Type Maps for SQLData Implementations

If you use the `SQLData` interface in a custom object class, then you must create type map entries that specify the custom object class to use in mapping the Oracle object type to Java. You can either use the default type map of the connection object or a type map that you specify when you retrieve the data from the result set. The `getObject` method of the `ResultSet` interface has a signature that lets you specify a type map. You can use either of the following:

```
rs.getObject(int columnIndex);

rs.getObject(int columnIndex, Map map);
```

When using a SQLData implementation, if you do not include a type map entry, then the object maps to the `oracle.jdbc.OracleStruct` interface by default. `OracleData` implementations, by

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contrast, have their own mapping functionality so that a type map entry is not required. When using an `OracleData` implementation, use the Oracle `getObject(int columnindex, OracleDataFactory factory)`method.

The type map relates a Java class to the SQL type name of an Oracle object. This one-to-one mapping is stored in a hash table as a keyword-value pair. When you read data from an Oracle object, the JDBC driver considers the type map to determine which Java class to use to materialize the data from the Oracle object type. When you write data to an Oracle object, the JDBC driver gets the SQL type name from the Java class by calling the `getSQLTypeName` method of the `SQLData` interface. The actual conversion between SQL and Java is performed by the driver.

The attributes of the Java class that corresponds to an Oracle object can use either Java native types or Oracle native types to store attributes.

Related Topics

- About Creating and Using Custom Object Classes for Oracle Objects

15.3.4 About Creating Type Map and Defining Mappings for a SQLData Implementation

This section covers the following topics:

- Overview of Creating a Type Map and Defining Mappings
- Adding Entries to an Existing Type Map
- Creating a New Type Map
- About Materializing Object Types not Specified in the Type Map

15.3.4.1 Overview of Creating a Type Map and Defining Mappings

When using a `SQLData` implementation, the JDBC applications programmer is responsible for providing a type map, which must be an instance of a class that implements the standard `java.util.Map` interface.

You have the option of creating your own class to accomplish this, but the standard `java.util.Hashtable` class meets the requirement.

`Hashtable` and other classes used for type maps implement a `put` method that takes keyword-value pairs as input, where each key is a fully qualified SQL type name and the corresponding value is an instance of a specified Java class.

A type map is associated with a connection instance. The standard `java.sql.Connection` interface and the Oracle-specific `oracle.jdbc.OracleConnection` interface include a `getTypeMap` method. Both return a `Map` object.

15.3.4.2 Adding Entries to an Existing Type Map

When a connection instance is first established, the default type map is empty. You must populate it.

Perform the following general steps to add entries to an existing type map:

1. Use the `getTypeMap` method of your `OracleConnection` object to return the type map object of the connection. The `getTypeMap` method returns a `java.util.Map` object. For example, presuming an `OracleConnection` instance `oraconn`:

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```
java.util.Map myMap = oraconn.getTypeMap();
```

> **Note**
>
> If the type map in the `OracleConnection` instance has not been initialized, then the first call to `getTypeMap` returns an empty map.

2. Use the `put` method of the type map to add map entries. The `put` method takes two arguments: a SQL type name string and an instance of a specified Java class that you want to map to.

   ```
   myMap.put(sqlTypeName, classObject);
   ```

   The *`sqlTypeName`* is a string that represents the fully qualified name of the SQL type in the database. The *`classObject`* is the Java class object to which you want to map the SQL type. Get the class object with the `Class.forName` method, as follows:

   ```
   myMap.put(sqlTypeName, Class.forName(className));
   ```

   For example, if you have a `PERSON` SQL data type defined in the `CORPORATE` database schema, then map it to a `Person` Java class defined as `Person` with this statement:

   ```
   myMap.put("CORPORATE.PERSON", Class.forName("Person"));
   oraconn.setTypeMap(newMap);
   ```

   The map has an entry that maps the `PERSON` SQL data type in the `CORPORATE` database to the `Person` Java class.

> **Note**
>
> SQL type names in the type map must be all uppercase, because that is how Oracle Database stores SQL names.

15.3.4.3 Creating a New Type Map

Perform the following general steps to create a new type map. This example uses an instance of `java.util.Hashtable`, which extends `java.util.Dictionary` and implements `java.util.Map`.

1. Create a new type map object.

   ```
   Hashtable newMap = new Hashtable();
   ```

2. Use the `put` method of the type map object to add entries to the map. For example, if you have an `EMPLOYEE` SQL type defined in the `CORPORATE` database, then you can map it to an `Employee` class object defined by `Employee.java`, as follows:

   ```
   newMap.put("CORPORATE.EMPLOYEE", class.forName("Employee"));
   ```

3. When you finish adding entries to the map, you must use the `setTypeMap` method of the `OracleConnection` object to overwrite the existing type map of the connection. For example:

   ```
   oraconn.setTypeMap(newMap);
   ```


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In this example, the `setTypeMap` method overwrites the original map of the `oraconn` connection object with `newMap`.

> **Note**
>
> The default type map of a connection instance is used when mapping is required but no map name is specified, such as for a result set `getObject` call that does not specify the map as input.

15.3.4.4 About Materializing Object Types not Specified in the Type Map

If you do not provide a type map with an appropriate entry when using a `getObject` call, then the JDBC driver will materialize an Oracle object as an instance of the `oracle.jdbc.OracleStruct` interface. If the Oracle object type contains embedded objects and they are not present in the type map, then the driver will materialize the embedded objects as instances of `oracle.jdbc.OracleStruct` as well. If the embedded objects are present in the type map, then a call to the `getAttributes` method will return embedded objects as instances of the specified Java classes from the type map.

15.3.5 About Reading and Writing Data with a SQLData Implementation

This section describes how to read data from an Oracle object or write data to an Oracle object if your corresponding Java class implements `SQLData`.

Reading SQLData Objects from a Result Set

The following text summarizes the steps to read data from an Oracle object into your Java application when you choose the `SQLData` implementation for your custom object class.

These steps assume you have already defined the Oracle object type, created the corresponding custom object class, updated the type map to define the mapping between the Oracle object and the Java class, and defined a statement object `stmt`.

1. Query the database to read the Oracle object into a JDBC result set.

   ```
   ResultSet rs = stmt.executeQuery("SELECT emp_col FROM personnel");
   ```

   The `PERSONNEL` table contains one column, `EMP_COL`, of SQL type `EMP_OBJECT`. This SQL type is defined in the type map to map to the Java class `Employee`.

2. Use the `getObject` method of Oracle result set to populate an instance of your custom object class with data from one row of the result set. The `getObject` method returns the user-defined `SQLData` object because the type map contains an entry for `Employee`.

   ```
   if (rs.next())
      Employee emp = (Employee)rs.getObject(1);
   ```

   Note that if the type map did not have an entry for the object, then the `getObject` method will return an `oracle.jdbc.OracleStruct` object. Cast the output to type `OracleStruct` because the `getObject` method signature returns the generic `java.lang.Object` type.

   ```
   if (rs.next())
      OracleStruct empstruct = (OracleStruct)rs.getObject(1);
   ```

   The `getObject` method calls `readSQL`, which, in turn, calls `read`*`XXX`* from the `SQLData` interface.

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> **Note**
>
> If you want to avoid using the defined type map, then use the `getSTRUCT` method. This method always returns a `STRUCT` object, even if there is a mapping entry in the type map.

3. If you have `get` methods in your custom object class, then use them to read data from your object attributes. For example, if `EMPLOYEE` has the attributes `EmpName` of type `CHAR` and `EmpNum` of type `NUMBER`, then provide a `getEmpName` method that returns a Java `String` and a `getEmpNum` method that returns an `int` value. Then call them in your Java application, as follows:

```
String empname = emp.getEmpName();
int empnumber = emp.getEmpNum();
```

Retrieving SQLData Objects from a Callable Statement OUT Parameter

Consider you have a `CallableStatement` instance, `cs`, that calls a PL/SQL function `GETEMPLOYEE`. The program passes an employee number to the function. The function returns the corresponding `Employee` object. To retrieve this object you do the following:

1. Prepare a `CallableStatement` to call the `GETEMPLOYEE` function, as follows:

```
CallableStatement ocs = conn.prepareCall("{ ? = call GETEMPLOYEE(?) }");
```

2. Declare the `empnumber` as the input parameter to `GETEMPLOYEE`. Register the `SQLData` object as the `OUT` parameter, with the type code `OracleTypes.STRUCT`. Then, run the statement. This can be done as follows:

```
cs.setInt(2, empnumber);
cs.registerOutParameter(1, OracleTypes.STRUCT, "EMP_OBJECT");
cs.execute();
```

3. Use the `getObject` method to retrieve the employee object.

```
Employee emp = (Employee)cs.getObject(1);
```

   If there is no type map entry, then the `getObject` method will return a `java.sql.Struct` object.

```
Struct emp = cs.getObject(1);
```

Passing SQLData Objects to a Callable Statement as an IN Parameter

Suppose you have a PL/SQL function `addEmployee(?)` that takes an `Employee` object as an `IN` parameter and adds it to the `PERSONNEL` table. In this example, `emp` is a valid `Employee` object.

1. Prepare an `CallableStatement` to call the `addEmployee(?)` function.

```
CallableStatement cs =
  conn.prepareCall("{ call addEmployee(?) }");
```

2. Use `setObject` to pass the `emp` object as an `IN` parameter to the callable statement. Then, call the statement.

```
cs.setObject(1, emp);
cs.execute();
```


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Writing Data to an Oracle Object Using a SQLData Implementation

The following text describes the steps in writing data to an Oracle object from your Java application when you choose the `SQLData` implementation for your custom object class.

This description assumes you have already defined the Oracle object type, created the corresponding Java class, and updated the type map to define the mapping between the Oracle object and the Java class.

1. If you have `set` methods in your custom object class, then use them to write data from Java variables in your application to attributes of your Java data type object.

   ```
   emp.setEmpName(empname);
   emp.setEmpNum(empnumber);
   ```

2. Prepare a statement that updates an Oracle object in a row of a database table, as appropriate, using the data provided in your Java data type object.

   ```
   PreparedStatement pstmt = conn.prepareStatement
                             ("INSERT INTO PERSONNEL VALUES (?)");
   ```

3. Use the `setObject` method of the prepared statement to bind your Java data type object to the prepared statement.

   ```
   pstmt.setObject(1, emp);
   ```

4. Run the statement, which updates the database.

   ```
   pstmt.executeUpdate();
   ```

15.3.6 About the OracleData Interface

You can create a custom object class that implements the `oracle.jdbc.OracleData` and the `oracle.jdbc.OracleDataFactory` interfaces to make an Oracle object and its attribute data available to Java applications. The `OracleData` and `OracleDataFactory` interfaces are Oracle-specific and are not a part of the JDBC standard.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `OracleData` and the `OracleDataFactory` interfaces replace the `ORAData` and the `ORADataFactory` interfaces.

Understanding the OracleData Interface Features

The `OracleData` interface has the following advantages:

- It supports Oracle extensions to the standard JDBC types.
- It does not require a type map to specify the names of the Java custom classes you want to create.
- It provides better performance. `OracleData` works directly with `Datum` types, the internal format the driver uses to hold Oracle objects.

The `OracleData` and the `OracleDataFactory` interfaces perform the following:

- The `toJDBCObject` method of the `OracleData` class transforms the data into an `oracle.jdbc.*` representation.

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- `OracleDataFactory` specifies a `create` method equivalent to a constructor for the custom object class. It creates and returns an `OracleData` instance. The JDBC driver uses the `create` method to return an instance of the custom object class to your Java application. It takes as input a `java.lang.Object` object and an integer indicating the corresponding SQL type code as specified in the `OracleTypes` class.

`OracleData` and `OracleDataFactory` have the following definitions:

```
package oracle.jdbc;
import java.sql.Connection;
import java.sql.SQLException;
public interface OracleData
{
   public Object toJDBCObject(Connection conn) throws SQLException;
}

package oracle.jdbc;
import java.sql.SQLException;
public interface OracleDataFactory
{
    public OracleData create(Object jdbcValue, int sqlType) throws SQLException;

}
```

Where *conn* represents the Connection object, *`jdbcValue`* represents an object of type `java.lang.object` that is to be used to initialize the Object being created, and *`sqlType`* represents the SQL type of the specified `Datum` object.

Retrieving and Inserting Object Data

The JDBC drivers provide the following methods to retrieve and insert object data as instances of `OracleData`.

You can retrieve the object data in one of the following ways:

- Use the following `getObject` method of the Oracle-specific `OracleResultSet` interface:

  ```
  ors.getObject(int col_index, OracleDataFactory factory
  );
  ```

  This method takes as input the column index of the data in your result set and an `OracleDataFactory` instance. For example, you can implement a `getOracleDataFactory` method in your custom object class to produce the `OracleDataFactory` instance to input to the `getObject` method. The type map is not required when using Java classes that implement `OracleData`.
- Use the standard `getObject(`*`index, map`*`)` method specified by the `ResultSet` interface to retrieve data as instances of `OracleData`. In this case, you must have an entry in the type map that identifies the factory class to be used for the given object type and its corresponding SQL type name.

You can insert object data in one of the following ways:

- Use the following `setObject` method of the Oracle-specific `OraclePreparedStatement` class:

  ```
  setObject(int bind_index, Object custom_object);
  ```

  This method takes as input the parameter index of the bind variable and an instance of `OracleData` as the name of the object containing the variable.

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- Use the standard `setObject` method specified by the `PreparedStatement` interface. You can also use this method, in its different forms, to insert `OracleData` instances without requiring a type map.

The following sections describe the `getObject` and `setObject` methods.

To continue the example of an Oracle object `EMPLOYEE`, you might have something like the following in your Java application:

```
OracleData obj = ors.getObject(1, Employee.getOracleDataFactory());
```

In this example, `ors` is an instance of the `OracleResultSet` interface, `getObject` is a method in the `OracleResultSet` interface used to retrieve an `OracleData` object, and the `EMPLOYEE` is in column 1 of the result set. The `static Employee.getOracleDataFactory` method will return an `OracleDataFactory` to the JDBC driver. The JDBC driver will call `create()` from this object, returning to your Java application an instance of the `Employee` class populated with data from the result set.

> **Note**
>
> - `OracleData` and `OracleDataFactory` are defined as separate interfaces so that different Java classes can implement them if you wish.
> - To use the `OracleData` interface, your custom object classes must import `oracle.jdbc.*`.

15.3.7 About Reading and Writing Data with an OracleData Implementation

This section describes how to read data from an Oracle object or write data to an Oracle object if your corresponding Java class implements `OracleData`.

Reading Data from an Oracle Object Using an OracleData Implementation

The following text summarizes the steps in reading data from an Oracle object into your Java application. These steps apply whether you implement `OracleData` manually or use Oracle JVM Web Service Call-Out utility to produce your custom object classes.

These steps assume you have already defined the Oracle object type, created the corresponding custom object class or had Oracle JVM Web Service Call-Out utility create it for you, and defined a statement object `stmt`.

1. Query the database to read the Oracle object into a result set, casting it to an Oracle result set.

   ```
   OracleResultSet ors = (OracleResultSet)stmt.executeQuery
                         ("SELECT Emp_col FROM PERSONNEL");
   ```

   Where `PERSONNEL` is a one-column table. The column name is `Emp_col` of type `Employee_object`.

2. Use the `getObject` method of Oracle result set to populate an instance of your custom object class with data from one row of the result set. The `getObject` method returns a `java.lang.Object` object, which you can cast to your specific custom object class.

   ```
   if (ors.next())
      Employee emp = (Employee)ors.getObject(1, Employee.getOracleDataFactory());
   ```

   or:

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```
if (ors.next())
   Object obj = ors.getObject(1, Employee.getOracleDataFactory());
```

This example assumes that `Employee` is the name of your custom object class and `ors` is the name of your `OracleResultSet` instance.

For example, if the SQL type name for your object is `EMPLOYEE`, then the corresponding Java class is `Employee`, which will implement `OracleData`. The corresponding Factory class is `EmployeeFactory`, which will implement `OracleDataFactory`.

Use this statement to declare the `EmployeeFactory` entry for your type map:

```
map.put ("EMPLOYEE", Class.forName ("EmployeeFactory"));
```

Then use the form of `getObject` where you specify the map object:

```
Employee emp = (Employee) rs.getObject (1, map);
```

If the default type map of the connection already has an entry that identifies the factory class to be used for the given object type and its corresponding SQL type name, then you can use this form of `getObject`:

```
Employee emp = (Employee) rs.getObject (1);
```

3. If you have `get` methods in your custom object class, then use them to read data from your object attributes into Java variables in your application. For example, if `EMPLOYEE` has `EmpName` of type `CHAR` and `EmpNum` of type `NUMBER`, provide a `getEmpName` method that returns a Java `String` and a `getEmpNum` method that returns an integer. Then call them in your Java application as follows:

```
String empname = emp.getEmpName();
int empnumber = emp.getEmpNum();
```

Writing Data to an Oracle Object Using an OracleData Implementation

The following text summarizes the steps in writing data to an Oracle object from your Java application. These steps apply whether you implement `OracleData` manually or use Oracle JVM Web Service Call-Out utility to produce your custom object classes.

These steps assume you have already defined the Oracle object type and created the corresponding custom object class.

> **Note**
>
> The type map is not used when you are performing database `INSERT` and `UPDATE` operations.

1. If you have `set` methods in your custom object class, then use them to write data from Java variables in your application to attributes of your Java data type object.

```
emp.setEmpName(empname);
emp.setEmpNum(empnumber);
```

2. Write an Oracle prepared statement that updates an Oracle object in a row of a database table, as appropriate, using the data provided in your Java data type object.

```
OraclePreparedStatement opstmt = conn.prepareStatement
   ("UPDATE PERSONNEL SET Employee = ? WHERE Employee.EmpNum = 28959);
```

This assumes `conn` is your `Connection` object.

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3. Use the `setObject` method of the `OraclePreparedStatement` interface to bind your Java data type object to the prepared statement.

   ```
   opstmt.setObject(1,emp);
   ```

   The `setObject` method calls the `toJDBCObject` method of the custom object class instance to retrieve an `oracle.jdbc.OracleStruct` object that can be written to the database.

> **Note**
>
> You can use your Java data type objects as either `IN` or `OUT` bind variables.

15.3.8 Additional Uses of OracleData

The `OracleData` interface offers far more flexibility than the `SQLData` interface. The `SQLData` interface is designed to let you customize the mapping of only Oracle object types to Java types of your choice. Implementing the `SQLData` interface lets the JDBC driver populate fields of a custom Java class instance from the original SQL object data, and the reverse, after performing the appropriate conversions between Java and SQL types.

The `OracleData` interface goes beyond supporting the customization of Oracle object types to Java types. It lets you provide a mapping between Java object types and *any* SQL type supported by the `oracle.sql` package.

You may find it useful to provide custom Java classes to wrap `oracle.sql.*` types and then implement customized conversions or functionality as well. The following are some possible scenarios:

- Performing encryption and decryption or validation of data
- Performing logging of values that have been read or are being written
- Parsing character columns, such as character fields containing URL information, into smaller components
- Mapping character strings into numeric constants
- Making data into more desirable Java formats, such as mapping a `DATE` field to `java.util.Date` format
- Customizing data representation, for example, data in a table column is in feet but you want it represented in meters after it is selected
- Serializing and deserializing Java objects

For example, use `OracleData` to store instances of Java objects that do not correspond to a particular SQL object type in the database in columns of SQL type `RAW`. The `create` method in `OracleDataFactory` would have to implement a conversion from an object of type `oracle.sql.RAW` to the desired Java object. The `toJDBCObject` method in `OracleData` would have to implement a conversion from the Java object to an `oracle.sql.RAW` object. You can also achieve this using Java serialization.

Upon retrieval, the JDBC driver transparently retrieves the raw bytes of data in the form of an `oracle.sql.RAW` and calls the `create` method of `OracleDataFactory` to convert the `oracle.sql.RAW` object to the desired Java class.

When you insert the Java object into the database, you can simply bind it to a column of type `RAW` to store it. The driver transparently calls the `OracleData.toJDBCObject` method to convert

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the Java object to an `oracle.sql.RAW` object. This object is then stored in a column of type `RAW` in the database.

Support for the `OracleData` interfaces is also highly efficient because the conversions are designed to work using `oracle.sql.*` formats, which happen to be the internal formats used by the JDBC drivers. Moreover, the type map, which is necessary for the `SQLData` interface, is not required when using Java classes that implement `OracleData`.

Related Topics

- About the OracleData Interface

15.4 Object-Type Inheritance

Object-type inheritance allows a new object type to be created by extending another object type. The new object type is then a subtype of the object type from which it extends. The subtype automatically inherits all the attributes and methods defined in the supertype. The subtype can add attributes and methods and overload or override methods inherited from the supertype.

Object-type inheritance introduces **substitutability**. Substitutability is the ability of a slot declared to hold a value of type `T` in addition to any subtype of type `T`. Oracle JDBC drivers handle substitutability transparently.

A database object is returned with its most specific type without losing information. For example, if the `STUDENT_T` object is stored in a `PERSON_T` slot, Oracle JDBC driver returns a Java object that represents the `STUDENT_T` object.

This section covers the following topics:

- About Creating Subtypes
- About Implementing Customized Classes for Subtypes
- About Retrieving Subtype Objects
- Creating Subtype Objects
- Sending Subtype Objects
- Accessing Subtype Data Fields
- Inheritance Metadata Methods

15.4.1 About Creating Subtypes

Create custom object classes if you want to have Java classes that explicitly correspond to the Oracle object types. If you have a hierarchy of object types, you may want a corresponding hierarchy of Java classes.

The most common way to create a database subtype in JDBC is to run a SQL `CREATE TYPE` command using the `execute` method of the `java.sql.Statement` interface. For example, you want to create a type inheritance hierarchy as depicted in the following figure:

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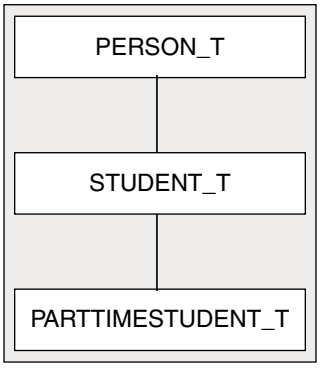
Figure 15-1 Type Inheritance Hierarchy



The JDBC code for this can be as follows:

```
Statement s = conn.createStatement();
s.execute ("CREATE TYPE Person_T (SSN NUMBER, name VARCHAR2(30),
  address VARCHAR2(255))");
s.execute ("CREATE TYPE Student_T UNDER Person_t (deptid NUMBER,
  major VARCHAR2(100))");
s.execute ("CREATE TYPE PartTimeStudent_t UNDER Student_t (numHours NUMBER)");
```

In the following code, the `foo` member procedure in type `ST` is overloaded and the member procedure `print` overwrites the copy it inherits from type `T`.

```
CREATE TYPE T AS OBJECT (...,
  MEMBER PROCEDURE foo(x NUMBER),
  MEMBER PROCEDURE Print(),
  ...
  NOT FINAL;

CREATE TYPE ST UNDER T (...,
  MEMBER PROCEDURE foo(x DATE),          <-- overload "foo"
  OVERRIDING MEMBER PROCEDURE Print(),   <-- override "print"
  STATIC FUNCTION bar(...) ...
  ...
  );
```

Once the subtypes have been created, they can be used as both columns of a base table as well as attributes of an object type.

> **See Also**
>
> *Oracle AI Database Object-Relational Developer's Guide*

15.4.2 About Implementing Customized Classes for Subtypes

In most cases, a customized Java class represents a database object type. When you create a customized Java class for a subtype, the Java class can either mirror the database object type hierarchy or not.

You can use either the `OracleData` or `SQLData` solution in creating classes to map to the hierarchy of object types.

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This section covers the following topics:

- About Using OracleData for Type Inheritance Hierarchy
- About UsingSQLData for Type Inheritance Hierarchy

15.4.2.1 About Using OracleData for Type Inheritance Hierarchy

Oracle recommends customized mappings, where Java classes implement the `oracle.sql.OracleData` interface. `OracleData` mapping requires the JDBC application to implement the `OracleData` and `OracleDataFactory` interfaces. The class implementing the `OracleDataFactory` interface contains a factory method that produces objects. Each object represents a database object.

The hierarchy of the class implementing the `OracleData` interface can mirror the database object type hierarchy. For example, the Java classes mapping to `PERSON_T` and `STUDENT_T` are as follows:

Person.java using OracleData

Code for the `Person.java` class which implements the `OracleData` and `OracleDataFactory` interfaces:

```
public static OracleDataFactory getOracleDataFactory()
  {
    return _personFactory;
  }

  public Person () {}

  public Person(NUMBER ssn, CHAR name, CHAR address)
  {
    this.ssn = ssn;
    this.name = name;
    this.address = address;
  }

  public Object toJDBCObject(OracleConnection c) throws SQLException
  {
    Object [] attributes = { ssn, name, address };
 Struct struct = c.createStruct("HR.PERSON_T", attributes);
    return struct;
  }

  public OracleData create(Object jdbcValue, int sqlType) throws SQLException
  {
    if (d == null) return null;
    Object [] attributes = ((STRUCT) d).getOracleAttributes();
    return new Person((NUMBER) attributes[0],
                      (CHAR) attributes[1],
                      (CHAR) attributes[2]);
  }
}
```

Student.java extending Person.java

Code for the `Student.java` class, which extends the `Person.java` class:

```
class Student extends Person
{
  static final Student _studentFactory = new Student ();
```


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```
  public NUMBER deptid;
  public CHAR major;

  public static OracleDataFactory getOracleDataFactory()
  {
    return _studentFactory;
  }

  public Student () {}

  public Student (NUMBER ssn, CHAR name, CHAR address,
                  NUMBER deptid, CHAR major)
  {
    super (ssn, name, address);
    this.deptid = deptid;
    this.major = major;
  }

  public Object toJDBCObject(OracleConnection c) throws SQLException
  {
    Object [] attributes = { ssn, name, address, deptid, major };
    Struct struct = c.createStruct("HR.STUDENT_T", attributes);
    return struct;
  }

  public OracleData create(Object jdbcValue, int sqlType) throws SQLException
  {
    if (d == null) return null;
    Object [] attributes = ((STRUCT) d).getOracleAttributes();
    return new Student((NUMBER) attributes[0],
                       (CHAR) attributes[1],
                       (CHAR) attributes[2],
                       (NUMBER) attributes[3],
                       (CHAR) attributes[4]);
  }
}
```

Customized classes that implement the `OracleData` interface do not have to mirror the database object type hierarchy. For example, you could have declared the `Student` class without a superclass. In this case, `Student` would contain fields to hold the inherited attributes from `PERSON_T` as well as the attributes declared by `STUDENT_T`.

OracleDataFactory Implementation

The JDBC application uses the factory class in querying the database to return instances of `Person` or its subclasses, as in the following example:

```
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  rset.getOracleData(1,Person.getOracleDataFactory());
  ...
}
```

A class implementing the `OracleDataFactory` interface should be able to produce instances of the associated custom object type, as well as instances of any subtype, or at least all the types you expect to support.

In the following example, the `PersonFactory.getOracleDataFactory` method returns a factory that can handle `PERSON_T`, `STUDENT_T`, and `PARTTIMESTUDENT_T` objects, by returning `person`, `student`, or `parttimestudent` Java instances.

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```
class PersonFactory implements OracleDataFactory
{
  static final PersonFactory _factory = new PersonFactory ();

  public static OracleDataFactory getOracleDataFactory()
  {
    return _factory;
  }

  public OracleData create(Object jdbcValue, int sqlType) throws SQLException
  {
    STRUCT s = (STRUCT) jdbcValue;
    if (s.getSQLTypeName ().equals ("HR.PERSON_T"))
      return Person.getOracleDataFactory ().create (jdbcValue, sqlType);
    else if (s.getSQLTypeName ().equals ("HR.STUDENT_T"))
      return Student.getOracleDataFactory ().create(jdbcValue, sqlType);
    else if (s.getSQLTypeName ().equals ("HR.PARTTIMESTUDENT_T"))
      return ParttimeStudent.getOracleDataFactory ().create(jdbcValue, sqlType);
    else
      return null;
  }
}
```

The following example assumes a table `tabl1`, such as the following:

```
CREATE TABLE tabl1 (idx NUMBER, person PERSON_T);
INSERT INTO tabl1 VALUES (1, PERSON_T (1000, 'HR', '100 Oracle Parkway'));
INSERT INTO tabl1 VALUES (2, STUDENT_T (1001, 'Peter', '200 Oracle Parkway', 101,
'CS'));
INSERT INTO tabl1 VALUES (3, PARTTIMESTUDENT_T (1002, 'David', '300 Oracle Parkway',
102, 'EE'));
```

15.4.2.2 About UsingSQLData for Type Inheritance Hierarchy

The customized classes that implement the `java.sql.SQLData` interface can mirror the database object type hierarchy. The `readSQL` and `writeSQL` methods of a subclass typically call the corresponding superclass methods to read or write the superclass attributes before reading or writing the subclass attributes. For example, the Java classes mapping to `PERSON_T` and `STUDENT_T` are as follows:

Person.java using SQLData

Code for the `Person.java` class, which implements the `SQLData` interface:

```
import java.sql.*;

public class Person implements SQLData
{
  private String sql_type;
  public int ssn;
  public String name;
  public String address;

  public Person () {}

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    sql_type = typeName;
    ssn = stream.readInt();
```


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```
    name = stream.readString();
    address = stream.readString();
  }

  public void writeSQL(SQLOutput stream) throws SQLException
  {
    stream.writeInt (ssn);
    stream.writeString (name);
    stream.writeString (address);
  }
}
```

Student.java extending Student.java

Code for the `Student.java` class, which extends the `Person.java` class:

```
import java.sql.*;

public class Student extends Person
{
  private String sql_type;
  public int deptid;
  public String major;

  public Student () { super(); }

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    super.readSQL (stream, typeName);    // read supertype attributes
    sql_type = typeName;
    deptid = stream.readInt();
    major = stream.readString();
  }

  public void writeSQL(SQLOutput stream) throws SQLException
  {
    super.writeSQL (stream);        // write supertype
                                    // attributes
    stream.writeInt (deptid);
    stream.writeString (major);
  }
}
```

Although not required, it is recommended that the customized classes, which implement the `SQLData` interface, mirror the database object type hierarchy. For example, you could have declared the `Student` class without a superclass. In this case, `Student` would contain fields to hold the inherited attributes from `PERSON_T` as well as the attributes declared by `STUDENT_T`.

Student.java using SQLData

Code for the `Student.java` class, which does not extend the `Person.java` class, but implements the SQLData interface directly:

```
import java.sql.*;

public class Student implements SQLData
{
  private String sql_type;

  public int ssn;
```


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```
  public String name;
  public String address;
  public int deptid;
  public String major;

  public Student () {}

  public String getSQLTypeName() throws SQLException { return sql_type; }

  public void readSQL(SQLInput stream, String typeName) throws SQLException
  {
    sql_type = typeName;
    ssn = stream.readInt();
    name = stream.readString();
    address = stream.readString();
    deptid = stream.readInt();
    major = stream.readString();
  }

  public void writeSQL(SQLOutput stream) throws SQLException
  {
    stream.writeInt (ssn);
    stream.writeString (name);
    stream.writeString (address);
    stream.writeInt (deptid);
    stream.writeString (major);
  }
}
```

15.4.3 About Retrieving Subtype Objects

In a typical JDBC application, a subtype object is returned as one of the following:

- A query result
- A PL/SQL `OUT` parameter
- A type attribute

You can use either the default mapping or the `SQLData` mapping or the `OracleData` mapping to retrieve a subtype.

Using Default Mapping

By default, a database object is returned as an instance of the `oracle.jdbc.OracleStruct` interface. This instance may represent an object of either the declared type or subtype of the declared type. If the `OracleStruct` interface represents a subtype object in the database, then it contains the attributes of its supertype as well as those defined in the subtype.

Oracle JDBC driver returns database objects in their most specific type. The JDBC application can use the `getSQLTypeName` method of the `OracleStruct` interface to determine the SQL type of the `STRUCT` object. The following code shows this:

```
// tab1.person column can store PERSON_T, STUDENT_T and PARTIMESTUDENT_T objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  oracle.sql.STRUCT s = (oracle.sql.STRUCT) rset.getObject(1);
  if (s != null)
    System.out.println (s.getSQLTypeName());    // print out the type name which
    // may be HR.PERSON_T, HR.STUDENT_T or HR.PARTTIMESTUDENT_T
}
```


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Using SQLData Mapping

With SQLData mapping, the JDBC driver returns the database object as an instance of the class implementing the SQLData interface.

To use SQLData mapping in retrieving database objects, do the following:

1. Implement the container classes that implement the SQLData interface for the desired object types.
2. Populate the connection type map with entries that specify what custom Java type corresponds to each Oracle object type.
3. Use the getObject method to access the SQL object values.

   The JDBC driver checks the type map for an entry match. If one exists, then the driver returns the database object as an instance of the class implementing the SQLData interface.

The following code shows the whole SQLData customized mapping process:

```
// The JDBC application developer implements Person.java for PERSON_T,
// Student.java for STUDENT_T
// and ParttimeStudent.java for PARTTIMESTUDEN_T.

Connection conn = ...;  // make a JDBC connection

// obtains the connection typemap
java.util.Map map = conn.getTypeMap ();

// populate the type map
map.put ("HR.PERSON_T", Class.forName ("Person"));
map.put ("HR.STUDENT_T", Class.forName ("Student"));
map.put ("HR.PARTTIMESTUDENT_T", Class.forName ("ParttimeStudent"));

// tab1.person column can store PERSON_T, STUDENT_T and PARTTIMESTUDENT_T objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  // "s" is instance of Person, Student or ParttimeStudent
  Object s = rset.getObject(1);

  if (s != null)
  {
    if (s instanceof Person)
      System.out.println ("This is a Person");
    else if (s instanceof Student)
      System.out.println ("This is a Student");
    else if (s instanceof ParttimeStudent)
      System.out.pritnln ("This is a PartimeStudent");
    else
      System.out.println ("Unknown type");
  }
}
```

The JDBC drivers check the connection type map for each call to the following:

- getObject method of the java.sql.ResultSet and java.sql.CallableStatement interfaces
- getAttribute method of the java.sql.Struct interface
- getArray method of the java.sql.Array interface

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- `getValue` method of the `oracle.sql.REF` interface

Using OracleData Mapping

With `OracleData` mapping, the JDBC driver returns the database object as an instance of the class implementing the `OracleData` interface.

Oracle JDBC driver needs to be informed of what Java class is mapped to the Oracle object type. The following are the two ways to inform Oracle JDBC drivers:

- The JDBC application uses the `getObject(int idx, OracleDataFactory f)` method to access database objects. The second parameter of the `getObject` method specifies an instance of the factory class that produces the customized class. The `getObject` method is available in the `OracleResultSet` and `OracleCallableStatement` interfaces.
- The JDBC application populates the connection type map with entries that specify what custom Java type corresponds to each Oracle object type. The `getObject` method is used to access the Oracle object values.

The second approach involves the use of the standard `getObject` method. The following code example demonstrates the first approach:

```
// tab1.person column can store both PERSON_T and STUDENT_T objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
{
  Object s = rset.getObject(1, PersonFactory.getOracleDataFactory());
  if (s != null)
  {
    if (s instanceof Person)
      System.out.println ("This is a Person");
    else if (s instanceof Student)
      System.out.println ("This is a Student");
    else if (s instanceof ParttimeStudent)
      System.out.pritnln ("This is a PartimeStudent");
    else
      System.out.println ("Unknown type");
  }
}
```

15.4.4 Creating Subtype Objects

There are cases where JDBC applications create database subtype objects with JDBC drivers. These objects are sent either to the database as bind variables or are used to exchange information within the JDBC application.

With customized mapping, the JDBC application creates either `SQLData`-based or `OracleData`-based objects, depending on the approach you choose, to represent database subtype objects. With default mapping, the JDBC application creates `STRUCT` objects to represent database subtype objects. All the data fields inherited from the supertype as well as all the fields defined in the subtype must have values. The following code demonstrates this:

```
Connection conn = ...   // make a JDBC connection
...
Object[] attrs = {
  new Integer(1234), "HR", "500 Oracle Parkway", // data fields defined in
                                                 // PERSON_T
  new Integer(102), "CS",                        // data fields defined in
                                                 // STUDENT_T
  new Integer(4)                                 // data fields defined in
                                                 // PARTTIMESTUDENT_T
```


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```
};
Struct s = conn.createStruct("HR.PARTTIMESTUDENT", attrs);
```

s is initialized with data fields inherited from PERSON_T and STUDENT_T, and data fields defined in PARTTIMESTUDENT_T.

15.4.5 Sending Subtype Objects

In a typical JDBC application, a Java object that represents a database object is sent to the databases as one of the following:

- A data manipulation language (DML) bind variable
- A PL/SQL IN parameter
- An object type attribute value

The Java object can be an instance of the STRUCT class or an instance of the class implementing either the SQLData or OracleData interface. Oracle JDBC driver will convert the Java object into the linearized format acceptable to the database SQL engine. Binding a subtype object is the same as binding a standard object.

15.4.6 Accessing Subtype Data Fields

While the logic to access subtype data fields is part of the customized class, this logic for default mapping is defined in the JDBC application itself. The database objects are returned as instances of the oracle.jdbc.OracleStruct class. The JDBC application needs to call one of the following access methods in the STRUCT class to access the data fields:

- Object[] getAttribute()
- oracle.sql.Datum[] getOracleAttribute()

Subtype Data Fields from the getAttribute Method

The getAttribute method of the java.sql.Struct interface is used in JDBC 2.0 to access object data fields. This method returns a java.lang.Object array, where each array element represents an object attribute. You can determine the individual element type by referencing the corresponding attribute type in the JDBC conversion matrix. For example, a SQL NUMBER attribute is converted to a java.math.BigDecimal object. The getAttribute method returns all the data fields defined in the supertype of the object type as well as data fields defined in the subtype. The supertype data fields are listed first followed by the subtype data fields.

Subtype Data Fields from the getOracleAttribute Method

The getOracleAttribute method is an Oracle extension method and is more efficient than the getAttribute method. The getOracleAttribute method returns an oracle.sql.Datum array to hold the data fields. Each element in the oracle.sql.Datum array represents an attribute. You can determine the individual element type by referencing the corresponding attribute type in the Oracle conversion matrix. For example, a SQL NUMBER attribute is converted to an oracle.sql.NUMBER object. The getOracleAttribute method returns all the attributes defined in the supertype of the object type, as well as attributes defined in the subtype. The supertype data fields are listed first followed by the subtype data fields.

The following code shows the use of the getAttribute method:

```
// tab1.person column can store PERSON_T, STUDENT_T and PARTIMESTUDENT_T objects
ResultSet rset = stmt.executeQuery ("select person from tab1");
while (rset.next())
```


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```
{
  oracle.sql.STRUCT s = (oracle.sql.STRUCT) rset.getObject(1);
  if (s != null)
  {
    String sqlname = s.getSQLTypeName();

    Object[] attrs = s.getAttribute();

    if (sqlname.equals ("HR.PERSON")
    {
      System.out.println ("ssn="+((BigDecimal)attrs[0]).intValue());
      System.out.println ("name="+((String)attrs[1]));
      System.out.println ("address="+((String)attrs[2]));
    }
    else if (sqlname.equals ("HR.STUDENT"))
    {
      System.out.println ("ssn="+((BigDecimal)attrs[0]).intValue());
      System.out.println ("name="+((String)attrs[1]));
      System.out.println ("address="+((String)attrs[2]));
      System.out.println ("deptid="+((BigDecimal)attrs[3]).intValue());
      System.out.println ("major="+((String)attrs[4]));
    }
    else if (sqlname.equals ("HR.PARTTIMESTUDENT"))
    {
      System.out.println ("ssn="+((BigDecimal)attrs[0]).intValue());
      System.out.println ("name="+((String)attrs[1]));
      System.out.println ("address="+((String)attrs[2]));
      System.out.println ("deptid="+((BigDecimal)attrs[3]).intValue());
      System.out.println ("major="+((String)attrs[4]));
      System.out.println ("numHours="+((BigDecimal)attrs[5]).intValue());
    }
    else
      throw new Exception ("Invalid type name: "+sqlname);
  }
}
rset.close ();
stmt.close ();
conn.close ();
```

15.4.7 Inheritance Metadata Methods

Oracle JDBC drivers provide a set of metadata methods to access inheritance properties. The inheritance metadata methods are defined in the `oracle.sql.StructDescriptor` and `oracle.jdbc.StructMetaData` classes.

The `StructMetaData` class provides inheritance metadata methods for subtype attributes. The `getMetaData` method of the `StructDescriptor` class returns an instance of `StructMetaData` of the type. The `StructMetaData` class contains the following inheritance metadata methods:

15.5 About Describing an Object Type

Oracle JDBC includes functionality to retrieve information about a structured object type regarding its attribute names and types. This is similar conceptually to retrieving information from a result set about its column names and types, and in fact uses an almost identical method.

This section covers the following topics:

- Functionality for Getting Object Metadata

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- Retrieving Object Metadata

15.5.1 Functionality for Getting Object Metadata

The `oracle.sql.StructDescriptor` class includes functionality to retrieve metadata about a structured object type. The `StructDescriptor` class has a `getMetaData` method with the same functionality as the standard `getMetaData` method available in result set objects. It returns a set of attribute information, such as attribute names and types. Call this method on a `StructDescriptor` object to get metadata about the Oracle object type that the `StructDescriptor` object describes.

The signature of the `StructDescriptor` class `getMetaData` method is the same as the signature specified for `getMetaData` in the standard `ResultSet` interface. The signature is as follows:

```
ResultSetMetaData getMetaData() throws SQLException
```

However, this method actually returns an instance of `oracle.jdbc.StructMetaData`, a class that supports structured object metadata in the same way that the standard `java.sql.ResultSetMetaData` interface specifies support for result set metadata.

The following method is also supported by `StructMetaData`:

```
String getOracleColumnClassName(int column) throws SQLException
```

This method returns the fully qualified name of the `oracle.sql.Datum` subclass whose instances are manufactured if the `OracleResultSet` interface `getOracleObject` method is called to retrieve the value of the specified attribute. For example, `oracle.sql.NUMBER`.

To use the `getOracleColumnClassName` method, you must cast the `ResultSetMetaData` object, which that was returned by the `getMetaData` method, to `StructMetaData`.

- **Note**

  In all the preceding method signatures, `column` is something of a misnomer. Where you specify a value of 4 for `column`, you really refer to the fourth attribute of the object.

15.5.2 Retrieving Object Metadata

Use the following steps to obtain metadata about a structured object type:

1. Create or acquire a `StructDescriptor` instance that describes the relevant structured object type.
2. Call the `getMetaData` method on the `StructDescriptor` instance.
3. Call the metadata getter methods, `getColumnName`, `getColumnType`, and `getColumnTypeName`, as desired.

Note

If one of the structured object attributes is itself a structured object, repeat steps 1 through 3.

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Example 15-1 Example

The following method shows how to retrieve information about the attributes of a structured object type. This includes the initial step of creating a `StructDescriptor` instance.

```
//
// Print out the ADT's attribute names and types
//
void getAttributeInfo (Connection conn, String type_name) throws SQLException
{

  // get the type descriptor
  StructDescriptor desc = StructDescriptor.createDescriptor (type_name, conn);

  // get type metadata
  ResultSetMetaData md = desc.getMetaData ();

  // get # of attrs of this type
  int numAttrs = desc.length ();

  // temporary buffers
  String attr_name;
  int attr_type;
  String attr_typeName;

  System.out.println ("Attributes of "+type_name+" :");
  for (int i=0; i<numAttrs; i++)
  {
    attr_name = md.getColumnName (i+1);
    attr_type = md.getColumnType (i+1);
    System.out.println (" index"+(i+1)+" name="+attr_name+" type="+attr_type);

    // drill down nested object
    if (attrType == OracleTypes.STRUCT)
    {
      attr_typeName = md.getColumnTypeName (i+1);

      // recursive calls to print out nested object metadata
      getAttributeInfo (conn, attr_typeName);
    }
  }
}
```


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16

Working with Large Objects and SecureFiles

Large Objects (LOBs) are a set of data types that are designed to hold large amounts of data. This chapter describes how to use Java Database Connectivity (JDBC) to access and manipulate LOBs and SecureFiles using either the data interface or the locator interface.

> **Note**
>
> Oracle is deprecating the methods `open()`, `close()`, and `isClosed()` in the interfaces `oracle.jdbc.OracleBlob`, `oracle.jdbc.OracleClob`, and `oracle.jdbc.OracleBfile`. These methods are replaced with the `openLob()`, `closeLob()` and `isClosedLob()` methods. The method `close()` conflicts with the type `java.lang.AutoCloseable`. Removing the proprietary method `close()` makes it possible for `OracleBlob`, `OracleClob`, and `OracleBfile` interfaces to extend the `AutoCloseable` interface at some future time. The `open()` and `isClosed()` methods will be removed and replaced to maintain rational names for these methods.

This chapter contains the following sections:

- The LOB Data Types
- Persistent LOBs
- Temporary LOBs
- Data Interface for LOBs
- Locator Interface for LOBs
- BFILEs
- JDBC Best Practices for LOB

16.1 The LOB Data Types

Oracle Database supports the following four LOB data types:

- Binary large object (BLOB)

  This data type is used for unstructured binary data.
- Character large object (CLOB)

  This data type is used for character data.
- National character large object (NCLOB)

  This data type is used for national character data.
- BFILE

  This data type is used for large binary data objects stored in operating system files, outside of database tablespaces.

BLOBs, CLOBs, and NCLOBs are stored persistently in a database table and all operations performed on these data types are under transaction control. You can also create temporary

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LOBs of types BLOB, CLOB, or NCLOB to hold transient data. Both persistent and temporary LOBs can be accessed and manipulated using the Data Interface and the Locator Interface.

BFILE is an Oracle proprietary data type that provides read-only access to data located outside the database tablespaces on tertiary storage devices, such as hard disks, network mounted files systems, CD-ROMs, PhotoCDs, and DVDs. BFILE data is not under transaction control and is not stored by database backups.

The PL/SQL language supports the LOB data types and the JDBC interface allows passing IN parameters to PL/SQL procedures or functions, and retrieval of OUT parameters or returns.

> **See Also**
>
> Introduction to Large Objects and SecureFiles

16.2 Persistent LOBs

A persistent LOB is a LOB instance that exists in a table row in the database. You can store persistent LOBs as SecureFiles or BasicFiles.

> **See Also**
>
> Persistent LOBs

SecureFiles is the default storage mechanism for LOBs in database tables. SecureFile LOBs can only be created in tablespaces managed with Automatic Segment Space Management (ASSM). Oracle strongly recommends SecureFiles for storing and managing BLOBs, CLOBs, and NCLOBs.

Following Features of Oracle SecureFiles are transparently available to JDBC programs through the existing APIs:

- Compression enables users to compress data to save disk space.
- Encryption provides an encryption facility that enables random read and write operations of the encrypted data.
- Deduplication enables automatically detect duplicate LOB data and conserve space by storing only one copy of the data.

isSecureFile Method

You can check whether or not your `BLOB` or `CLOB` data uses Oracle SecureFile storage. To achieve this, use the following method from the `oracle.jdbc.OracleBlob` or the `oracle.jdbc.OracleClob` class:

```
public boolean isSecureFile() throws SQLException
```

If this method returns `true`, then your data uses SecureFile storage.

Both persistent and temporary LOBs can be accessed and manipulated using the Data Interface and the Locator Interface.

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> **See Also**
>
> - Data Interface for LOBs
> - Locator Interface for LOBs

16.3 Temporary LOBs

You can use temporary LOBs to store transient data. Temporary LOBs reside in either the PGA memory or the temporary tablespace, depending on their size.

You can insert temporary LOBs into a regular database table. In such a case, a permanent copy of the LOB is created and stored.

> **See Also**
>
> Temporary LOBs

Creating a Temporary LOB

You create a temporary LOB with the static `createTemporary` method, defined in both the `oracle.sql.BLOB` and `oracle.sql.CLOB` classes. You can also create a temporary LOB by using the connection factory methods available in JDBC 4.0. The Oracle JDBC drivers implement the factory methods, `createBlob`, `createClob`, and `createNClob` in the `java.sql.Connection` interface to create temporary LOBs.

Freeing a Temporary LOB

You free a temporary LOB using the `freeTemporary` method. You can test whether a LOB is temporary or not by calling the `isTemporary` method. If the LOB was created by calling the `createTemporary` method, then the `isTemporary` method returns `true`, else it returns `false`.

Starting with Oracle Database Release 21c, you do not need to check whether a LOB is temporary or persistent before releasing the temporary LOB. If you call the `DBMS_LOB.FREETEMPORARY` procedure or the `OCILobFreeTemporary()` function on a LOB, it will perform either of the following operations:

- For a temporary LOB, it will release the LOB.
- For a persistent LOB, it will do nothing (no-op).

> **Note**
>
> - You must free any temporary LOBs before ending the session or call. If you do not free a temporary LOB, then it will make the storage used by that LOB in the database unavailable. Frequent failure to free temporary LOBs will result in filling up temporary table space with unavailable LOB storage.
> - The JDBC 4.0 `free` method, present in the `java.sql.Blob`, `java.sql.Clob`, and `java.sql.NClob` interfaces, supersedes the `freeTemporary` method.

Both persistent and temporary LOBs can be accessed and manipulated using the Data Interface and the Locator Interface.

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> **See Also**
>
> - Data Interface for LOBs
> - Locator Interface for LOBs

16.4 Data Interface for LOBs

The data interface for LOBs includes a set of Java and OCI APIs that are extended to work with LOB data types.

The data interface uses standard JDBC methods such as the `getString` method and the `setBytes` method to read and write LOB data. Unlike the standard `java.sql.Blob`, `java.sql.Clob`, and `java.sql.NClob` interfaces, the data interface does not provide random access capability, that is, it does not use LOB locator and cannot access data beyond a size of 2 gigabytes.

> **See Also**
>
> Data Interface for LOBs

You can use the data interface for LOBs to store and manipulate character data and binary data in a LOB column as if it were stored in the corresponding legacy data types like `VARCHAR2`, `LONG`, `RAW`, and so on. This section describes the following topics:

- Input
- Output
- CallableSatement and IN OUT Parameter
- Size Limitations

16.4.1 Input

The `setBytes`, `setBinaryStream`, `setString`, `setCharacterStream`, and `setAsciiStream` methods of the `PreparedStatement` interface are extended to enhance the ability to work with `BLOB`, `CLOB`, and `NCLOB` target columns. If the length of the data is known, then for better performance, use the versions of `setBinaryStream` or `setCharacterStream` methods that accept the data length as a parameter.

> **Note**
>
> These methods do not work with `BFILE` data because it is read-only.

For the JDBC Oracle Call Interface (OCI) and Thin drivers, there is no limitation on the size of the `byte` array, `String`, or the length specified for the stream functions, except the limits imposed by the Java language.

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> **Note**
>
> In Java, the array size is limited to positive Java `int` or 2 gigabytes of size.

For the server-side internal driver, currently there is a limitation of 32767 bytes for operations on SQL statements, such as an `INSERT` statement. This limitation does not apply for PL/SQL statements. You can use the following workaround for an `INSERT` statement, where you can wrap the LOB in a PL/SQL block:

```
BEGIN
 INSERT id, c INTO clob_tab VALUES(?,?);
END;
```

Input Modes for LOBs

LOBs have the following three input modes:

- Direct binding

  This binding is limited in size but most efficient. It places the data for all input columns inline in the block of data sent to the server. All data, including multiple executions of a batch, is sent in a single network operation.

- Stream binding

  This binding places data at the end. It limits batch size to one and may require multiple round trips to complete.

- LOB binding

  This binding creates a temporary LOB, copies data to the LOB, and binds the LOB locator. The temporary LOB is automatically freed after execution. The operation to create the temporary LOB and then to writing to the LOB requires multiple round trips. The input of the locators may be batched.

You must bear in mind the following automatic switching of the input mode for LOBs:

- For SQL statements:
  - The `setBytes` and `setBinaryStream` methods use direct binding for data less than 32767 bytes.
  - The `setBytes` and `setBinaryStream` methods use stream binding for data larger than 32767 bytes.
  - Starting from JDBC 4.0, there are two forms of `setAsciiStream`, `setBinaryStream`, and `setCharacterStream` methods. The form that accepts a `long` argument as length, uses LOB binding for length larger than 2147483648. The form, where the length is not specified, always uses LOB binding.
  - The `setString`, `setCharacterStream`, and `setAsciiStream` methods use direct binding for data smaller than 32767 characters.
  - The `setString`, `setCharacterStream`, and `setAsciiStream` methods use stream binding for data larger than 32766 characters.
- For PL/SQL statements:
  - The `setBytes` and `setBinary` stream methods use direct binding for data less than 32767 bytes.
  - The `setBytes` and `setBinaryStream` methods use LOB binding for data larger than 32766 bytes.

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  - The `setString`, `setCharacterStream`, and `setAsciiStream` methods use direct binding for data smaller than 32767 bytes in the database character set.
  - The `setString`, `setCharacterStream`, and `setAsciiStream` methods use LOB binding for data larger than 32766 bytes in the database character set.
- Forced conversion to LOBs
  The `setBytesForBlob` and `setStringForClob` methods, present in the `oracle.jdbc.OraclePreparedStatement` interface, use LOB binding for any data size.

Impact of Automatic Switching of Input Mode

The automatic switching of the input mode for large data has impact on certain programs. Previously, you used to get `ORA-17157` errors for attempts to use the `setString` method for `String` values larger than 32766 characters. Now, depending on the type of the target parameter, an error may occur while the statement is executed or the operation may succeed.

Another impact is that the automatic switching may result in additional server-side parsing to adapt to the change in the parameter type. This results in a performance effect, if the data sizes vary above and below the limit for repeated executions of the statement. Switching to the stream modes effects batching as well.

16.4.2 Output

The `getBytes`, `getBinaryStream`, `getString`, `getCharacterStream`, and `getAsciiStream` methods of the `ResultSet` and `CallableStatement` interfaces work with `BLOB`, `CLOB`, and `BFILE` columns or `OUT` parameters. These methods work for any `LOB` of length less than 2147483648.

> **Note**
>
> The `getString` and `getNString` methods cannot be used for retrieving BLOB column values.

The data interface operates by accessing the `LOB` locators within the driver and is transparent to the application programming interface.

You can read `BFILE` data, and read and write `BLOB` or `CLOB` data using the `defineColumnType` method. To read, use the `defineColumnType(nn, Types.LONGVARBINARY)` or the `defineColumnType(nn,Types.LONGVARCHAR)` method on the column. This produces a direct stream on the data as if it were a `LONG RAW` or `LONG` column, and gives the fastest read performance on LOBs.

You can also use LOB prefetching to reduce or eliminate any additional database round trips.

Related Topics

- New Methods for National Character Set Type Data in JDK 6
- Locator Interface for LOBs
  Locators are small data structures, which contain information that may be used to access the actual data of the LOB. In a database table, the locator is stored directly in the table, while the data may be in the table or in separate storage.

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16.4.3 CallableSatement and IN OUT Parameter

If you have an `IN OUT CLOB` parameter of a stored procedure and want to use the `setString` method for setting the value for this parameter, then for any `IN` and `OUT` parameter, the binds must be of the same type.

> **Note**
>
> It is a PL/SQL requirement that the Java types used as input and output for an IN OUT parameter must be the same. The automatic switching of types done by the extensions described in this chapter may cause problems with this.

The automatic switching of the input mode causes problems if you are not sure of the data sizes. For example, if you know that neither the input data nor the output data will ever be larger than 32766 bytes, then you can use the `setString` method for the input parameter and register the `OUT` parameter as `Types.VARCHAR` and use the `getString` method for the output parameter.

A better solution is to change the stored procedure to have separate `IN` and `OUT` parameters. That is, if you have the following piece of code in your application:

```
CREATE PROCEDURE clob_proc( c IN OUT CLOB );
```

then, change it to:

```
CREATE PROCEDURE clob_proc( c_in IN CLOB, c_out OUT CLOB );
```

Another workaround is to use a container block to make the call. The `clob_proc` procedure can be wrapped with a Java String to use for the `prepareCall` statement, as follows:

```
"DECLARE c_temp; BEGIN c_temp := ?; clob_proc( c_temp); ? := c_temp; END;"
```

In either case, you can use the `setString` method on the first parameter and the `registerOutParameter` method with `Types.CLOB` on the second.

16.4.4 Size Limitations

You must be aware of the effect on the performance of the Java memory management system due to creation of a very large `byte` array or a `String`. Read the information provided by your Java virtual machine (JVM) vendor about the impact of very large data elements on memory management, and consider using the stream interfaces instead.

16.5 Locator Interface for LOBs

Locators are small data structures, which contain information that may be used to access the actual data of the LOB. In a database table, the locator is stored directly in the table, while the data may be in the table or in separate storage.

> **See Also**
>
> Locator Interface for LOBs

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Starting from JDBC 4.0, you must use the `java.sql.Blob`, `java.sql.Clob`, and `java.sql.NClob` interfaces for performing read and write operations on LOBs. These interfaces provide random access to the data in the LOB.

The Oracle implementation classes `oracle.sql.BLOB`, `oracle.sql.CLOB`, and `oracle.sql.NCLOB` store the locator and access the data with it. The `oracle.sql.BLOB` and `oracle.sql.CLOB` classes implement the `java.sql.Blob` and `java.sql.Clob` interfaces respectively.

Note

Oracle recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about these interface.

In Oracle Database 23ai, the Oracle JDBC drivers support the JDBC 4.0 `java.sql.NClob` interface in `ojdbc11.jar`, which is compiled with JDK 11 and the JDBC 4.3 `java.sql.NClob` interface in `ojdbc17.jar`, which is compiled with JDK 17.

In contrast, the `oracle.sql.BFILE` is an Oracle extension, without a corresponding `java.sql` interface.

See Also

JDBC Javadoc

16.5.1 LOB prefetching

For the current release of JDBC drivers, the number of round trips is reduced by prefetching the metadata such as the LOB length, the chunk size, and the beginning of the LOB data, along with the locator during regular fetch operations.

If you select LOB columns into a result set, then some or all of the data is prefetched to the client, when the locator is fetched. It saves the first round trip to retrieve data by deferring all preceding operations until fetching from the locator.

Note

- LOBs are not prefetched in abstract data types (ADTs) like STRUCTs and ARRAYs. This behavior is exhibited even if you set the value of the `oracle.jdbc.defaultLobPrefetchSize` connection property. If the client application performs an operation that depends on the value of a LOB, which is embedded in such a data type, then additional round-trips are required to fetch the value.
- The benefits of prefetching are more for small LOBs and less for larger LOBs.
- You must be aware of the possible memory consumption while setting large LOB prefetch sizes in combination with a large row prefetch size and a large number of LOB columns.

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The default prefetch size is 32768. You can specify the prefetch size in bytes for BLOBs and in characters for CLOBs, using the `oracle.jdbc.defaultLobPrefetchSize` connection property. You can override the value of this property in the following two ways:

- **At the statement level:** By using the `oracle.jdbc.OracleStatement.setLobPrefetchSize(int)` method
- **At the column level:** By using the form of the `defineColumnType` method that takes length as argument

> **See Also**
>
> JDBC Javadoc

16.5.2 LOB Open and Close Operations

This section discusses how to open and close your LOBs.

This section discusses how to open and close your LOBs. The JDBC implementation of this functionality is provided using the following methods available in the `oracle.sql.BLOB` and `oracle.sql.CLOB` interfaces:

- `void open (int mode)`
- `void close()`
- `boolean isOpen()`

> **Note**
>
> You do not have to necessarily open and close your LOBs. You may choose to open and close those for performance reasons.

> **See Also**
>
> LOB Open and Close Operations

16.6 BFILEs

BFILEs are data objects stored in operating system files, outside the database tablespaces. Data stored in a table column of type BFILE is physically located in an operating system file, not in the database. The BFILE column stores a reference to the operating system file.

BFILEs are read-only. The body of the data resides in the operating system (OS) file system and you can write to BFILEs using only OS tools and commands. You can create a BFILE for an existing external file by executing the appropriate SQL statement using either JDBC APIs or any other way to execute SQL. However, using SQL or JDBC, you cannot create an OS file that a BFILE refers to. Such OS files are created only by an external process that has access to server file systems.

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> **See Also**
>
> BFILEs

This section describes how to use file locators to perform read and write operations on BFILEs. This section covers the following topics:

- Retrieving BFILE Locators
- Inserting BFILES

Retrieving BFILE Locators

Both the BFILE data type and the `oracle.jdbc.OracleBfile` interface to work with the BFILEs are Oracle proprietary. So, there is no standard interface for them. You must use Oracle extensions for this type of data.

If you have a standard JDBC result set or callable statement object that includes BFILE locators, then you can access the locators by using the standard result set `getObject`method. This method returns an `oracle.jdbc.OracleBfile` object.

You can also access the locators by casting your result set to `OracleResultSet` or your callable statement to `OracleCallableStatement` and using the `getOracleObject` or `getBFILE` method.

> **Note**
>
> If you are using `getObject` or `getOracleObject` methods, then remember to cast the output, as necessary.

Once you have a locator, you can access the BFILE data through the APIs present in the `oracle.jdbc.OracleBfile` class. These APIs are similar to the read methods of the `oracle.jdbc.OracleBfile` interface.

Inserting BFILES

You can use an instance of the `oracle.jdbc.OracleBfile` interface as input to a SQL statement or to a PL/SQL procedure. You can achieve this by performing one of the following:

- Use the standard `setObject` method.
- Cast the statement to `OraclePreparedStatement` or `OracleCallableStatement`, and use the `setOracleObject` or `setBFILE` method. These methods take the parameter index and an `oracle.jdbc.OracleBfile` object as input.

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Note

- There is no standard `java.sql` interface for BFILEs.
- Use the `getBFILE` methods in the `OracleResultSet` and `OracleCallableStatement` interfaces to retrieve an `oracle.jdbc.OracleBfile` object. The `setBFILE` methods in `OraclePreparedStatement` and `OracleCallableStatement` interfaces accept `oracle.jdbc.OracleBfile` object as an argument. Use these methods to write to a BFILE.
- Oracle recommends that you use the `getBFILE`, `setBFILE`, and `updateBFILE` methods instead of the `getBfile`, `setBfile`, and `updateBfile` methods. For example, use the `setBFILE` method instead of the `setBfile` method.

16.7 JDBC Best Practices for LOB

You can enhance the performance of your applications if you reduce the number of round-trips to the database. This section describes how to minimize the number of round-trips to the database.

If you know the maximum size of your LOB data, and you intend to perform read or write operation on the entire LOB, then use the Data Interface following these guidelines:

- For read operations, define the LOB as character type or binary type using the `DefineColumnType` method.
- For write operations, bind the LOB as character type or binary type using the `setString` or the `setBytes` method.

If you do not know the maximum size of your LOB data, then use the LOB APIs with LOB prefetching for read operations. Also, define the LOB prefetch size to a value that can accommodate majority of the LOB values in the column.

See Also

LOB prefetching

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17

Using Oracle Object References

This chapter describes the standard Java Database Connectivity (JDBC) that let you access and manipulate object references.

This section discusses the following topics:

- Oracle Extensions for Object References
- Retrieving and Passing an Object Reference
- Accessing and Updating Object Values Through an Object Reference

17.1 Oracle Extensions for Object References

Oracle supports the use of references to database objects. Oracle JDBC provides support for object references as:

- Columns in a `SELECT` clause
- IN or OUT bind variables
- Attributes in an Oracle object
- Elements in a collection type object

In SQL, an object reference (`REF`) is strongly typed. For example, a reference to an `EMPLOYEE` object would be defined as an `EMPLOYEE REF`, not just a `REF`.

When you select an object reference, be aware that you are retrieving only a pointer to an object, not the object itself. You have the choice of materializing the reference as a `java.sql.Ref` instance for portability, or materializing it as an instance of a custom Java class that you have created in advance, which is strongly typed. Custom Java classes used for object references are referred to as **custom reference classes** and must implement the `oracle.jdbc.OracleData` interface.

You can retrieve a `REF` instance through a result set or callable statement object, and pass an updated `REF` instance back to the database through a prepared statement or callable statement object. The `REF` class includes functionality to get and set underlying object attribute values, and get the SQL base type name of the underlying object.

Custom reference classes include this same functionality, as well as having the advantage of being strongly typed. This can help you find coding errors during compilation that might not otherwise be discovered until run time.

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> **Note**
>
> - If you are using the `oracle.jdbc.OracleData` interface for custom object classes, then you will presumably use `OracleData` for corresponding custom reference classes as well. However, if you are using the standard `java.sql.SQLData` interface for custom object classes, then you can only use weak Java types for references. The `SQLData` interface is for mapping SQL object types only.
> - You can create and retrieve `REF` objects in your JDBC application only by running SQL statements. There is no JDBC-specific functionality for creating and retrieving `REF` objects.
> - You cannot have a reference to an array, even though arrays, like objects, are structured types.

17.2 Retrieving and Passing an Object Reference

This section discusses JDBC functionality for retrieving and passing object references. It covers the following topics:

- Retrieving an Object Reference from a Result Set
- Retrieving an Object Reference from a Callable Statement
- Passing an Object Reference to a Prepared Statement

17.2.1 Retrieving an Object Reference from a Result Set

To demonstrate how to retrieve object references, the following example first defines an Oracle object type `ADDRESS`, which is then referenced in the `PEOPLE` table:

```
create type ADDRESS as object
   (street_name     VARCHAR2(30),
    house_no        NUMBER);

create table PEOPLE
    (col1 VARCHAR2(30),
     col2 NUMBER,
     col3 REF ADDRESS);
```

The `ADDRESS` object type has two attributes: a street name and a house number. The `PEOPLE` table has three columns: a column for character data, a column for numeric data, and a column containing a reference to an `ADDRESS` object.

To retrieve an object reference, follow these general steps:

1. Use a standard SQL `SELECT` statement to retrieve the reference from a database table `REF` column.
2. Use `getRef` to get the address reference from the result set into an `OracleRef` instance.
3. Let `Address` be the Java custom class corresponding to the SQL object type `ADDRESS`.
4. Add the correspondence between the Java class `Address` and the SQL type `ADDRESS` to your type map.
5. Use the `getObject` method to retrieve the contents of the `Address` reference. Cast the output to `Address`.

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The PEOPLE database table is defined earlier in this section. The code for the preceding steps, except the step of adding Address to the type map, is as follows:

```
ResultSet rs = stmt.executeQuery("SELECT col3 FROM PEOPLE");
while (rs.next())
{
   OracleRef ref = rs.getRef(1);
   Address a = (Address)ref.getObject();
}
```

> **Note**
>
> In the preceding code, stmt is a previously defined statement object.

17.2.2 Retrieving an Object Reference from a Callable Statement

To retrieve an object reference as an OUT parameter in PL/SQL blocks, you must register the bind type for your OUT parameter.

1. Cast your callable statement to OracleCallableStatement, as follows:

   ```
   OracleCallableStatement ocs =
      (OracleCallableStatement)conn.prepareCall("{? = call func()}");
   ```

2. Register the OUT parameter with the following form of the registerOutParameter method:

   ```
   ocs.registerOutParameter (int param_index, int sql_type, String sql_type_name);
   ```

   param_index is the parameter index and *sql_type* is the SQL type code. The *sql_type_name* is the name of the structured object type that this reference is used for. For example, if the OUT parameter is a reference to an ADDRESS object, then ADDRESS is the *sql_type_name* that should be passed in.

3. Run the call, as follows:

   ```
   ocs.execute();
   ```

17.2.3 Passing an Object Reference to a Prepared Statement

Pass an object reference to a prepared statement in the same way as you would pass any other SQL type. Use either the setObject method or the setREF method of a prepared statement object.

Use a prepared statement to update an address reference based on ROWID, as follows:

```
PreparedStatement pstmt =
   conn.prepareStatement ("update PEOPLE set ADDR_REF = ? where ROWID = ?");
pstmt.setRef (1, addr_ref);
    pstmt.setRowId (2, rowid);
```

17.3 Accessing and Updating Object Values Through an Object Reference

You can use the Ref object setObject method to update the value of an object in the database through an object reference. To do this, you must first retrieve the reference to the database object and create a Java object that corresponds to the database object.

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For example, you can use the code in the "Retrieving and Passing an Object Reference" section to retrieve the reference to a database `ADDRESS` object, as shown in the following code snippet:

```
ResultSet rs = stmt.executeQuery("SELECT col3 FROM PEOPLE");
if (rs.next())
{
   Ref ref = rs.getRef(1);
   Address a = (Address)ref.getObject();
}
```

Then, you can create a Java `Address` object that corresponds to the database `ADDRESS` object. Use the `setObject` method of the `Ref` interface to set the value of the database object, as follows:

```
Address addr = new Address(...);
ref.setObject(addr);
```

Here, the `setValue` method updates the database `ADDRESS` object immediately.

Related Topics

- Retrieving and Passing an Object Reference

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18

Working with Oracle Collections

This chapter describes Oracle extensions to standard Java Database Connectivity (JDBC) that let you access and manipulate Oracle collections, which map to Java arrays, and their data. The following topics are discussed:

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.ARRAY` class is deprecated and replaced with the `oracle.jdbc.OracleArray` interface, which is a part of the `oracle.jdbc` package. Oracle recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleArray` interface.

- Oracle Extensions for Collections
- Overview of Collection Functionality
- ARRAY Performance Extension Methods
- Creating and Using Arrays
- Using a Type Map to Map Array Elements

18.1 Oracle Extensions for Collections

This section covers the following topics:

- Overview of Oracle Collections
- Choices in Materializing Collections
- Creating Collections
- Creating Multilevel Collection Types

18.1.1 Overview of Oracle Collections

An Oracle collection, either a variable array (VARRAY) or a nested table in the database, maps to an array in Java. JDBC 2.0 arrays are used to materialize Oracle collections in Java. The terms collection and array are sometimes used interchangeably. However, collection is more appropriate on the database side and array is more appropriate on the JDBC application side.

Oracle supports only named collections, where you specify a SQL type name to describe a type of collection. JDBC enables you to use arrays as any of the following:

- Columns in a `SELECT` clause
- `IN` or `OUT` bind variables
- Attributes in an Oracle object

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- Elements of other arrays

18.1.2 Choices in Materializing Collections

In your application, you have the choice of materializing a collection as an instance of the `oracle.sql.ARRAY` class, which is weakly typed, or materializing it as an instance of a custom Java class that you have created in advance, which is strongly typed. Custom Java classes used for collections are referred to as custom collection classes. A custom collection class must implement the Oracle `oracle.jdbc.OracleData` interface. In addition, the custom class or a companion class must implement `oracle.jdbc.OracleDataFactory`. The standard `java.sql.SQLData` interface is for mapping SQL object types only.

The `oracle.sql.ARRAY` class implements the standard `java.sql.Array` interface.

The `ARRAY` class includes functionality to retrieve the array as a whole, retrieve a subset of the array elements, and retrieve the SQL base type name of the array elements. However, you cannot write to the array, because there are no setter methods.

Custom collection classes, as with the `ARRAY` class, enable you to retrieve all or part of the array and get the SQL base type name. They also have the advantage of being strongly typed, which can help you find coding errors during compilation that might not otherwise be discovered until run time.

> **Note**
>
> There is no difference in the code between accessing VARRAYs and accessing nested tables. `ARRAY` class methods can determine if they are being applied to a VARRAY or nested table, and respond by taking the appropriate actions.

18.1.3 Creating Collections

Because Oracle supports only named collections, you must declare a particular `VARRAY` type name or nested table type name. VARRAY and nested table are not types themselves, but categories of types.

A SQL type name is assigned to a collection when you create it using the SQL `CREATE TYPE` statement:

```
CREATE TYPE <sql_type_name> AS <datatype>;
```

A VARRAY is an array of varying size. It has an ordered set of data elements, and all the elements are of the same data type. Each element has an index, which is a number corresponding to the position of the element in the VARRAY. The number of elements in a VARRAY is the size of the VARRAY. You must specify a maximum size when you declare the `VARRAY` type. For example:

```
CREATE TYPE myNumType AS VARRAY(10) OF NUMBER;
```

This statement defines `myNumType` as a SQL type name that describes a VARRAY of `NUMBER` values that can contain no more than 10 elements.

A nested table is an unordered set of data elements, all of the same data type. The database stores a nested table in a separate table which has a single column, and the type of that column is a built-in type or an object type. If the table is an object type, then it can also be

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viewed as a multi-column table, with a column for each attribute of the object type. You can create a nested table as follows:

```
CREATE TYPE myNumList AS TABLE OF integer;
```

This statement identifies `myNumList` as a SQL type name that defines the table type used for the nested tables of the type `INTEGER`.

18.1.4 Creating Multilevel Collection Types

The most common way to create a new multilevel collection type in JDBC is to pass the SQL `CREATE TYPE` statement to the `execute` method of the `java.sql.Statement` class. The following code creates a one-level nested table, `first_level`, and a two- levels nested table, `second_level`:

```
Connection conn = ....                                  // make a database
                                                        // connection
Statement stmt = conn.createStatement();                // open a database
                                                        // cursor
stmt.execute("CREATE TYPE first_level AS TABLE OF NUMBER");  // create a nested
                                                        // table of number
stmt.execute("CREATE TYPE second_level AS TABLE OF first_level"); // create a
           // two-levels nested table
...        // other operations here
stmt.close();                                           // release the
                                                        // resource
conn.close();                                           // close the
                                                        // database connection
```

Once the multilevel collection types have been created, they can be used as both columns of a base table as well as attributes of a object type.

> **Note**
>
> Multilevel collection types are available only for Oracle9*i* and later.

18.2 Overview of Collection Functionality

You can obtain collection data in an array instance through a result set or callable statement and pass it back as a bind variable in a prepared statement or callable statement.

The `oracle.sql.ARRAY` class, which implements the standard `java.sql.Array` interface, provides the necessary functionality to access and update the data of an Oracle collection.

This section covers Array Getter and Setter Methods. Use the following result set, callable statement, and prepared statement methods to retrieve and pass collections as Java arrays.

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> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.ARRAY` class is deprecated and replaced with the `oracle.jdbc.OracleArray` interface, which is a part of the `oracle.jdbc` package. Oracle recommends you to use the methods available in the `java.sql` package, where possible, for standard compatibility and methods available in the `oracle.jdbc` package for Oracle specific extensions. Refer to MoS Note 1364193.1 for more information about the `oracle.jdbc.OracleArray` interface.

Result Set and Callable Statement Getter Methods

The `OracleResultSet` and `OracleCallableStatement` interfaces support `getARRAY` and `getArray` methods to retrieve `ARRAY` objects as output parameters, either as `oracle.sql.ARRAY` instances or `java.sql.Array` instances. You can also use the `getObject` method. These methods take as input a `String` column name or `int` column index.

> **Note**
>
> The Oracle JDBC drivers cache array and structure descriptors. This provides enormous performance benefits; however, it means that if you change the underlying type definition of an array type in the database, the cached descriptor for that array type will become stale and your application will receive a `SQLException`.

Prepared and Callable Statement Setter Methods

The `OraclePreparedStatement` and `OracleCallableStatement` classes support `setARRAY` and `setArray` methods to take updated `ARRAY` objects as bind variables and pass them to the database. You can also use the `setObject` method. These methods take as input a `String` parameter name or `int` parameter index as well as an `oracle.sql.ARRAY` instance or a `java.sql.Array` instance.

18.3 ARRAY Performance Extension Methods

This section discusses the following topics:

- About Accessing oracle.sql.ARRAY Elements as Arrays of Java Primitive Types
- ARRAY Automatic Element Buffering
- ARRAY Automatic Indexing

18.3.1 About Accessing oracle.sql.ARRAY Elements as Arrays of Java Primitive Types

The `oracle.sql.ARRAY` class contains methods that return array elements as Java primitive types. These methods enable you to access collection elements more efficiently than accessing them as `Datum` instances and then converting each `Datum` instance to its Java primitive value.

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> **Note**
>
> These specialized methods of the `oracle.sql.ARRAY` class are restricted to numeric collections.

Each method using the first signature returns collection elements as an *XXX*`[]`, where *XXX* is a Java primitive type. Each method using the second signature returns a slice of the collection containing the number of elements specified by `count`, starting at the `index` location.

18.3.2 ARRAY Automatic Element Buffering

Oracle JDBC driver provides public methods to enable and disable buffering of `ARRAY` contents.

The following methods are included with the `oracle.sql.ARRAY` class:

- `setAutoBuffering`
- `getAutoBuffering`

It is advisable to enable auto-buffering in a JDBC application when the `ARRAY` elements will be accessed more than once by the `getAttributes` and `getArray` methods, presuming the `ARRAY` data is able to fit into the Java Virtual Machine (JVM) memory without overflow.

> **Note**
>
> Buffering the converted elements may cause the JDBC application to consume a significant amount of memory.

When you enable auto-buffering, the `oracle.sql.ARRAY` object keeps a local copy of all the converted elements. This data is retained so that a second access of this information does not require going through the data format conversion process.

18.3.3 ARRAY Automatic Indexing

If an array is in auto-indexing mode, then the array object maintains an index table to hasten array element access.

The `oracle.sql.ARRAY` class contains the following methods to support automatic array-indexing:

- `setAutoIndexing(boolean)`
- `setAutoIndexing(boolean, int)`

By default, auto-indexing is not enabled. For a JDBC application, enable auto-indexing for `ARRAY` objects if random access of array elements may occur through the `getArray` and `getResultSet` methods.

18.4 Creating and Using Arrays

This section discusses how to create array objects and how to retrieve and pass collections as array objects, including the following topics.

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- Creating ARRAY Objects
- Retrieving an Array and Its Elements
- Passing Arrays to Statement Objects

18.4.1 Creating ARRAY Objects

> **Note**
>
> Oracle JDBC does not support the JDBC 4.0 method `createArrayOf` method of `java.sql.Connection` interface. This method only allows anonymous array types, while all Oracle array types are named. Use the Oracle specific method `oracle.jdbc.OracleConnection.createARRAY` instead.

This section describes how to create `ARRAY` objects. This section covers the following topics:

- Steps in Creating ARRAY Objects
- Example 18-1

Steps in Creating ARRAY Objects

Starting from Oracle Database 11*g* Release 1, you can use the `createARRAY` factory method of `oracle.jdbc.OracleConnection` interface to create an array object. The factory method for creating arrays has been defined as follows:

```
public ARRAY createARRAY(java.lang.String typeName,java.lang.Object elements)throws
SQLException
```

where, `typeName` is the name of the SQL type of the created object and `elements` is the elements of the created object.

Perform the following to create an array:

1. Create a collection with the `CREATE TYPE` statement as follows:

   ```
   CREATE TYPE elements AS varray(22) OF NUMBER(5,2);
   ```

   The two possibilities for the contents of `elements` are:

   - An array of Java primitives. For example, `int[]`.
   - An array of Java objects, such as *xxx*`[]`, where *xxx* is the name of a Java class. For example, `Integer[]`.

   > **Note**
   >
   > The `setARRAY`, `setArray`, and `setObject` methods of the `OraclePreparedStatement` class take an object of the type `oracle.sql.ARRAY` as an argument, not an array of objects.

2. Construct the `ARRAY` object by passing the Java string specifying the user-defined SQL type name of the array and a Java object containing the individual elements you want the array to contain.

   ```
   ARRAY array = oracle.jdbc.OracleConnection.createARRAY(sql_type_name, elements);
   ```


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> **Note**
>
> The name of the collection type is not the same as the type name of the elements. For example:
>
> ```
> CREATE TYPE person AS object
>             (c1 NUMBER(5), c2 VARCHAR2(30));
> CREATE TYPE array_of_persons AS varray(10)
>           OF person;
> ```
>
> In the preceding statements, the name of the collection type is `ARRAY_OF_PERSON`. The SQL type name of the collection elements is `PERSON`.

Example 18-1 Creating Multilevel Collections

As with single-level collections, the JDBC application can create an `oracle.sql.ARRAY` instance to represent a multilevel collection, and then send the instance to the database. The same `createARRAY` factory method you use to create single-level collections, can be used to create multilevel collections as well. To create a single-level collection, the elements are a one dimensional Java array, while to create a multilevel collection, the elements can be either an array of `oracle.sql.ARRAY[]` elements or a nested Java array or the combinations.

The following code shows how to create collection types with a nested Java array:

```
// prepare the multilevel collection elements as a nested Java array
int[][][] elements = { {{1}, {1, 2}}, {{2}, {2, 3}}, {{3}, {3, 4}} };

// create the ARRAY using the factory method
ARRAY array = oracle.jdbc.OracleConnection.createARRAY(sql_type_name, elements);
```

18.4.2 Retrieving an Array and Its Elements

This section first discusses how to retrieve an `ARRAY` instance as a whole from a result set, and then how to retrieve the elements from the `ARRAY` instance. This section covers the following topics:

- About Retrieving the Array
- Data Retrieval Methods
- Comparing the Data Retrieval Methods
- Retrieving Elements of a Structured Object Array According to a Type Map
- Retrieving a Subset of Array Elements
- Retrieving Array Elements into an oracle.sql.Datum Array
- About Accessing Multilevel Collection Elements

18.4.2.1 About Retrieving the Array

You can retrieve a SQL array from a result set by casting the result set to `OracleResultSet` and using the `getARRAY` method, which returns an `oracle.sql.ARRAY` object. If you want to avoid casting the result set, then you can get the data with the standard `getObject` method specified by the `java.sql.ResultSet` interface and cast the output to `oracle.sql.ARRAY`.

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18.4.2.2 Data Retrieval Methods

Once you have an `ARRAY` object, you can retrieve the data using one of these three overloaded methods of the `oracle.sql.ARRAY` class:

- `getArray`
- `getOracleArray`
- `getResultSet`

Oracle also provides methods that enable you to retrieve all the elements of an array, or a subset.

> **Note**
>
> In case you are working with an array of structured objects, Oracle provides versions of these three methods that enable you to specify a type map so that you can choose how to map the objects to Java.

getOracleArray

The `getOracleArray` method is an Oracle-specific extension that is not specified in the standard `Array` interface. The `getOracleArray` method retrieves the element values of the array into a `Datum[]` array. The elements are of the `oracle.sql.*` data type corresponding to the SQL type of the data in the original array.

For an array of structured objects, this method will use `oracle.jdbc.OracleStruct` instances for the elements.

Oracle also provides a `getOracleArray(`*`index`*`,`*`count`*`) method` to get a subset of the array elements.

getResultSet

The `getResultSet` method returns a result set that contains elements of the array designated by the `ARRAY` object. The result set contains one row for each array element, with two columns in each row. The first column stores the index into the array for that element, and the second column stores the element value. In the case of VARRAYs, the index represents the position of the element in the array. In the case of nested tables, which are by definition unordered, the index reflects only the return order of the elements in the particular query.

Oracle recommends using `getResultSet` when getting data from nested tables. Nested tables can have an unlimited number of elements. The `ResultSet` object returned by the method initially points at the first row of data. You get the contents of the nested table by using the `next` method and the appropriate `get`*`XXX`* method. In contrast, `getArray` returns the entire contents of the nested table at one time.

The `getResultSet` method uses the default type map of the connection to determine the mapping between the SQL type of the Oracle object and its corresponding Java data type. If you do not want to use the default type map of the connection, another version of the method, `getResultSet(`*`map`*`)`, enables you to specify an alternate type map.

Oracle also provides the `getResultSet(`*`index`*`,`*`count`*`)` and `getResultSet(`*`index`*`,`*`count`*`,`*`map`*`)` methods to retrieve a subset of the array elements.

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getArray

The `getArray` method is a standard JDBC method that returns the array elements as a `java.lang.Object`, which you can cast as appropriate. The elements are converted to the Java types corresponding to the SQL type of the data in the original array.

Oracle also provides a `getArray(index,count)` method to retrieve a subset of the array elements.

18.4.2.3 Comparing the Data Retrieval Methods

If you use `getOracleArray` to return the array elements, then the use by that method of `oracle.sql.Datum` instances avoids the expense of data conversion from SQL to Java. The non-character data inside the instance of a `Datum` class or any of its subclass remains in raw SQL format.

If you use `getResultSet` to return an array of primitive data types, then the JDBC driver returns a `ResultSet` object that contains, for each element, the index into the array for the element and the element value. For example:

```
ResultSet rset = intArray.getResultSet();
```

In this case, the result set contains one row for each array element, with two columns in each row. The first column stores the index into the array and the second column stores the element value.

If the elements of an array are of a SQL type that maps to a Java type, then `getArray` returns an array of elements of this Java type. The return type of the `getArray` method is `java.lang.Object`. Therefore, the result must be cast before it can be used.

```
BigDecimal[] values = (BigDecimal[]) intArray.getArray();
```

Here `intArray` is an `oracle.sql.ARRAY`, corresponding to a VARRAY of type `NUMBER`. The `values` array contains an array of elements of type `java.math.BigDecimal`, because the SQL `NUMBER` data type maps to Java `BigDecimal`, by default, according to Oracle JDBC drivers.

> **Note**
>
> Using `BigDecimal` is a resource-intensive operation in Java. Because Oracle JDBC maps numeric SQL data to `BigDecimal` by default, using `getArray` may impact performance, and is not recommended for numeric collections.

18.4.2.4 Retrieving Elements of a Structured Object Array According to a Type Map

By default, if you are working with an array whose elements are structured objects, and you use `getArray` or `getResultSet`, then the Oracle objects in the array will be mapped to their corresponding Java data types according to the default mapping. This is because these methods use the default type map of the connection to determine the mapping.

However, if you do not want default behavior, then you can use the `getArray(map)` or `getResultSet(map)` method to specify a type map that contains alternate mappings. If there are entries in the type map corresponding to the Oracle objects in the array, then each object in the array is mapped to the corresponding Java type specified in the type map. For example:

```
Object[] object = (Object[])objArray.getArray(map);
```


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Where `objArray` is an `oracle.sql.ARRAY` object and `map` is a `java.util.Map` object.

If the type map does not contain an entry for a particular Oracle object, then the element is returned as an `oracle.jdbc.OracleStruct` object.

The `getResultSet(map)` method behaves similarly to the `getArray(map)` method.

Related Topics

- Using a Type Map to Map Array Elements

18.4.2.5 Retrieving a Subset of Array Elements

If you do not want to retrieve the entire contents of an array, then you can use signatures of `getArray`, `getResultSet`, and `getOracleArray` that let you retrieve a subset. To retrieve a subset of the array, pass in an index and a count to indicate where in the array you want to start and how many elements you want to retrieve. As previously described, you can specify a type map or use the default type map for your connection to convert to Java types. For example:

```
Object object = arr.getArray(index, count, map);
Object object = arr.getArray(index, count);
```

Similar examples using `getResultSet` are:

```
ResultSet rset = arr.getResultSet(index, count, map);
ResultSet rset = arr.getResultSet(index, count);
```

A similar example using `getOracleArray` is:

```
Datum[] arr = arr.getOracleArray(index, count);
```

Where *arr* is an `oracle.sql.ARRAY` object, *index* is type `long`, *count* is type `int`, and *map* is a `java.util.Map` object.

> **Note**
>
> There is no performance advantage in retrieving a subset of an array, as opposed to the entire array.

18.4.2.6 Retrieving Array Elements into an oracle.sql.Datum Array

Use `getOracleArray` to return an `oracle.sql.Datum[]` array. The elements of the returned array is of `oracle.sql.*` type that correspond to the SQL data type of the elements of the original array. For example:

```
Datum arraydata[] = arr.getOracleArray();
```

`arr` is an `oracle.sql.ARRAY` object.

The following example assumes that a connection object `conn` and a statement object `stmt` have already been created. In the example, an array with the SQL type name `NUM_ARRAY` is created to store a VARRAY of `NUMBER` data. The `NUM_ARRAY` is in turn stored in a table `VARRAY_TABLE`.

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A query selects the contents of the VARRAY_TABLE. The result set is cast to OracleResultSet. The getARRAY method is applied to it to retrieve the array data into my_array, which is an oracle.sql.ARRAY object.

Because my_array is of type oracle.sql.ARRAY, you can apply the methods getSQLTypeName and getBaseType to it to return the name of the SQL type of each element in the array and its integer code.

The program then prints the contents of the array. Because the contents of NUM_ARRAY are of the SQL data type NUMBER, the elements of my_array are of the type, BigDecimal. Before you can use the elements, they must first be cast to BigDecimal. In the for loop, the individual values of the array are cast to BigDecimal and printed to standard output.

```
stmt.execute ("CREATE TYPE num_varray AS VARRAY(10) OF NUMBER(12, 2)");
stmt.execute ("CREATE TABLE varray_table (col1 num_varray)");
stmt.execute ("INSERT INTO varray_table VALUES (num_varray(100, 200))");

ResultSet rs = stmt.executeQuery("SELECT * FROM varray_table");
ARRAY my_array = ((OracleResultSet)rs).getARRAY(1);

// return the SQL type names, integer codes,
// and lengths of the columns
System.out.println ("Array is of type " + array.getSQLTypeName());
System.out.println ("Array element is of type code " + array.getBaseType());
System.out.println ("Array is of length " + array.length());

// get Array elements
BigDecimal[] values = (BigDecimal[]) my_array.getArray();

for (int i=0; i<values.length; i++)
{
   BigDecimal out_value = (BigDecimal) values[i];
   System.out.println(">> index " + i + " = " + out_value.intValue());
}
```

Note that if you use getResultSet to obtain the array, then you must would first get the result set object, and then use the next method to iterate through it. Notice the use of the parameter indexes in the getInt method to retrieve the element index and the element value.

```
ResultSet rset = my_array.getResultSet();
while (rset.next())
{
    // The first column contains the element index and the
    // second column contains the element value
    System.out.println(">> index " + rset.getInt(1)+" = " + rset.getInt(2));
}
```

18.4.2.7 About Accessing Multilevel Collection Elements

The oracle.sql.ARRAY class provides three methods, which are overloaded, to access collection elements. The JDBC drivers extend these methods to support multilevel collections. These methods are:

- getArray method
- getOracleArray method
- getResultSet method

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The `getArray` method returns a Java array that holds the collection elements. The array element type is determined by the collection element type and the JDBC default conversion matrix.

For example, the `getArray` method returns a `java.math.BigDecimal` array for collection of SQL `NUMBER`. The `getOracleArray` method returns a `Datum` array that holds the collection elements in `Datum` format. For multilevel collections, the `getArray` and `getOracleArray` methods both return a Java array of `oracle.sql.ARRAY` elements.

The `getResultSet` method returns a `ResultSet` object that wraps the multilevel collection elements. For multilevel collections, the JDBC applications use the `getObject`, `getARRAY`, or `getArray` method of the `ResultSet` class to access the collection elements as instances of `oracle.sql.ARRAY`.

The following code shows how to use the `getOracleArray`, `getArray`, and `getResultSet` methods:

```
Connection conn = ...;          // make a JDBC connection
Statement stmt = conn.createStatement ();
ResultSet rset = stmt.executeQuery ("select col2 from tab2 where idx=1");

while (rset.next())
{
  ARRAY varray3 = (ARRAY) rset.getObject (1);
  Object varrayElems = varray3.getArray (1);
// access array elements of "varray3"
  Datum[] varray3Elems = (Datum[]) varrayElems;

  for (int i=0; i<varray3Elems.length; i++)
  {
    ARRAY varray2 = (ARRAY) varray3Elems[i];
    Datum[] varray2Elems = varray2.getOracleArray();
    // access array elements of  "varray2"

    for (int j=0; j<varray2Elems.length; j++)
    {
      ARRAY varray1 = (ARRAY) varray2Elems[j];
      ResultSet varray1Elems = varray1.getResultSet();
      // access array elements   of "varray1"

      while (varray1Elems.next())
        System.out.println ("idx="+varray1Elems.getInt(1)+"
          value="+varray1Elems.getInt(2));
    }
  }
}
rset.close ();
stmt.close ();
conn.close ();
```

18.4.3 Passing Arrays to Statement Objects

This section discusses how to pass arrays to prepared statement objects or callable statement objects.

Passing an Array to a Prepared Statement

Pass an array to a prepared statement as follows.

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> **Note**
>
> you can use arrays as either `IN` or `OUT` bind variables.

1. Define the array that you want to pass to the prepared statement as an `oracle.sql.ARRAY` object.

   ```
   ARRAY array = oracle.jdbc.OracleConnection.createARRAY(sql_type_name, elements);
   ```

   `sql_type_name` is a Java string specifying the user-defined SQL type name of the array and *`elements`* is a `java.lang.Object` containing a Java array of the elements.
2. Create a `java.sql.PreparedStatement` object containing the SQL statement to be run.
3. Cast your prepared statement to `OraclePreparedStatement`, and use `setARRAY` to pass the array to the prepared statement.

   ```
   (OraclePreparedStatement)stmt.setARRAY(parameterIndex, array);
   ```

   `parameterIndex` is the parameter index and *`array`* is the `oracle.sql.ARRAY` object you constructed previously.
4. Run the prepared statement.

Passing an Array to a Callable Statement

To retrieve a collection as an `OUT` parameter in PL/SQL blocks, perform the following to register the bind type for your `OUT` parameter.

1. Cast your callable statement to `OracleCallableStatement`, as follows:

   ```
   OracleCallableStatement ocs = (OracleCallableStatement)conn.prepareCall("{? = call
   func()}");
   ```
2. Register the `OUT` parameter with the following form of the `registerOutParameter` method:

   ```
   ocs.registerOutParameter
           (int param_index, int sql_type, string sql_type_name);
   ```

   `param_index` is the parameter index, *`sql_type`* is the SQL type code, and *`sql_type_name`* is the name of the array type. In this case, the *`sql_type`* is `OracleTypes.ARRAY`.
3. Run the call, as follows:

   ```
   ocs.execute();
   ```
4. Get the value, as follows:

   ```
   oracle.sql.ARRAY array = ocs.getARRAY(1);
   ```

18.5 Using a Type Map to Map Array Elements

If your array contains Oracle objects, then you can use a type map to associate the objects in the array with the corresponding Java class. If you do not specify a type map, or if the type map does not contain an entry for a particular Oracle object, then each element is returned as an `oracle.jdbc.OracleStruct` object.

If you want the type map to determine the mapping between the Oracle objects in the array and their associated Java classes, then you must add an appropriate entry to the map.

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The following example illustrates how you can use a type map to map the elements of an array to a custom Java object class. In this case, the array is a nested table. The example begins by defining an EMPLOYEE object that has a name attribute and employee number attribute. EMPLOYEE_LIST is a nested table type of EMPLOYEE objects. Then an EMPLOYEE_TABLE is created to store the names of departments within a corporation and the employees associated with each department. In the EMPLOYEE_TABLE, the employees are stored in the form of EMPLOYEE_LIST tables.

```
stmt.execute("CREATE TYPE EMPLOYEE AS OBJECT
            (EmpName VARCHAR2(50),EmpNo INTEGER))");

stmt.execute("CREATE TYPE EMPLOYEE_LIST AS TABLE OF EMPLOYEE");

stmt.execute("CREATE TABLE EMPLOYEE_TABLE (DeptName VARCHAR2(20),
     Employees EMPLOYEE_LIST) NESTED TABLE Employees STORE AS ntable1");

stmt.execute("INSERT INTO EMPLOYEE_TABLE VALUES ("SALES", EMPLOYEE_LIST
            (EMPLOYEE('Susan Smith', 123), EMPLOYEE('Lee Brown', 124)))");
```

If you want to retrieve all the employees belonging to the SALES department into an array of instances of the custom object class EmployeeObj, then you must add an entry to the type map to specify mapping between the EMPLOYEE SQL type and the EmployeeObj custom object class.

To do this, first create your statement and result set objects, then select the EMPLOYEE_LIST associated with the SALES department into the result set. Cast the result set to OracleResultSet so you can use the getARRAY method to retrieve the EMPLOYEE_LIST into an ARRAY object (employeeArray in the following example).

The EmployeeObj custom object class in this example implements the SQLData interface.

```
Statement s = conn.createStatement();
OracleResultSet rs = (OracleResultSet)s.executeQuery
       ("SELECT Employees FROM employee_table WHERE DeptName = 'SALES'");

// get the array object
ARRAY employeeArray = ((OracleResultSet)rs).getARRAY(1);
```

Now that you have the EMPLOYEE_LIST object, get the existing type map and add an entry that maps the EMPLOYEE SQL type to the EmployeeObj Java type.

```
// add type map entry to map SQL type
// "EMPLOYEE" to Java type "EmployeeObj"
Map map = conn.getTypeMap();
map.put("EMPLOYEE", Class.forName("EmployeeObj"));
```

Next, retrieve the SQL EMPLOYEE objects from the EMPLOYEE_LIST. To do this, call the getArray method of the employeeArray array object. This method returns an array of objects. The getArray method returns the EMPLOYEE objects into the employees object array.

```
// Retrieve array elements
Object[] employees = (Object[]) employeeArray.getArray();
```

Finally, create a loop to assign each of the EMPLOYEE SQL objects to the EmployeeObj Java object emp.

```
// Each array element is mapped to EmployeeObj object.
for (int i=0; i<employees.length; i++)
{
   EmployeeObj emp = (EmployeeObj) employees[i];
   ...
}
```


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19

Result Set

Standard Java Database Connectivity (JDBC) features in Java Development Kit (JDK) include enhancements to result set functionality, such as processing forward or backward, positioning relatively or absolutely, seeing changes to the database made internally or externally, and updating result set data and then copying the changes to the database.

This chapter discusses the following topics:

- Oracle JDBC Implementation Overview for Result Set Support
- Resultset Limitations and Downgrade Rules
- About Avoiding Update Conflicts
- Row Fetch Size
- About Refetching Rows
- About Viewing Database Changes Made Internally and Externally

19.1 Oracle JDBC Implementation Overview for Result Set Support

This section discusses key aspects of the Oracle JDBC implementation of result set support for scrollability, through use of a client-side cache, and for updatability, through use of `ROWID`s.

It is permissible for customers to implement their own client-side caching mechanism, and Oracle provides an interface to use in doing so.

Oracle JDBC Implementation for Result Set Scrollability

Because the underlying server does *not* support scrollable cursors, Oracle JDBC must implement scrollability in a separate layer.

It is important to be aware that this is accomplished by using a client-side memory cache to store rows of a scrollable result set.

> **Note**
>
> Because all rows of any scrollable result set are stored in the client-side cache, a situation, where the result set contains many rows, many columns, or very large columns, might cause the client-side Java Virtual Machine (JVM) to fail. Do not specify scrollability for a large result set.

Oracle JDBC Implementation for Result Set Updatability

To support updatability, Oracle JDBC uses `ROWID` to uniquely identify database rows that appear in a result set. For every query into an updatable result set, Oracle JDBC driver automatically retrieves the `ROWID` along with the columns you select.

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> **Note**
>
> Client-side caching is not required by updatability in and of itself. In particular, a forward-only updatable result set will not require a client-side cache.

19.2 Resultset Limitations and Downgrade Rules

Some types of result sets are not feasible for certain kinds of queries. If you specify an unfeasible result set type or concurrency type for the query you run, then the JDBC driver follows a set of rules to determine the best feasible types to use instead.

The actual result set type and concurrency type are determined when the statement is run, with the driver issuing a `SQLWarning` on the statement object if the desired result set type or concurrency type is not feasible. The `SQLWarning` object will contain the reason why the requested type was not feasible. Check for warnings to verify whether you received the type of result set that you requested.

Result Set Limitations

The following limitations are placed on queries for enhanced result sets. Failure to follow these guidelines results in the JDBC driver choosing an alternative result set type or concurrency type.

To produce an updatable result set:

- A query can select from only a single table and cannot contain any join operations.

  In addition, for inserts to be feasible, the query must select all non-nullable columns and all columns that do not have a default value.
- A query cannot use `SELECT *`.

  However, there is a workaround for this.
- A query must select table columns only.

  It cannot select derived columns or aggregates, such as the `SUM` or `MAX` of a set of columns.

To produce a scroll-sensitive result set:

- A query cannot use `SELECT *`.

  However, there is a workaround for this.
- A query can select from only a single table.

Scrollable and updatable result sets cannot have any column as `Stream`. When the server has to fetch a `Stream` column, it reduces the fetch size to one and blocks all columns following the `Stream` column until the `Stream` column is read. As a result, columns cannot be fetched in bulk and scrolled through.

Workaround

As a workaround for the `SELECT *` limitation, you can use table aliases, as shown in the following example:

```
SELECT t.* FROM TABLE t ...
```


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> **Note**
>
> There is a simple way to determine if your query will probably produce a scroll-sensitive or updatable result set: If you can legally add a `ROWID` column to the query list, then the query is probably suitable for either a scroll-sensitive or an updatable result set.

Result Set Downgrade Rules

If the specified result set type or concurrency type is not feasible, then Oracle JDBC driver uses the following rules in choosing alternate types:

- If the specified result set type is `TYPE_SCROLL_SENSITIVE`, but the JDBC driver cannot fulfill that request, then the driver attempts a downgrade to `TYPE_SCROLL_INSENSITIVE`.
- If the specified or downgraded result set type is `TYPE_SCROLL_INSENSITIVE`, but the JDBC driver cannot fulfill that request, then the driver attempts a downgrade to `TYPE_FORWARD_ONLY`.
- If the specified concurrency type is `CONCUR_UPDATABLE`, but the JDBC driver cannot fulfill that request, then the JDBC driver attempts a downgrade to `CONCUR_READ_ONLY`.

> **Note**
>
> Any manipulations of the result set type and concurrency type by the JDBC driver are independent of each other.

Verifying Result Set Type and Concurrency Type

After a query has been run, you can verify the result set type and concurrency type that the JDBC driver actually used, by calling methods on the result set object.

- `int getType() throws SQLException`

  This method returns an `int` value for the result set type used for the query. `ResultSet.TYPE_FORWARD_ONLY`, `ResultSet.TYPE_SCROLL_SENSITIVE`, or `ResultSet.TYPE_SCROLL_INSENSITIVE` are the possible values.

- `int getConcurrency() throws SQLException`

  This method returns an `int` value for the concurrency type used for the query. `ResultSet.CONCUR_READ_ONLY` or `ResultSet.CONCUR_UPDATABLE` are the possible values.

19.3 About Avoiding Update Conflicts

It is important to be aware of the following facts regarding updatable result sets with the JDBC drivers:

- The drivers do not enforce write locks for an updatable result set.
- The drivers do not check for conflicts with a result set `DELETE` or `UPDATE` operation.

A conflict will occur if you try to perform a `DELETE` or `UPDATE` operation on a row updated by another committed transaction.

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Oracle JDBC drivers use the `ROWID` to uniquely identify a row in a database table. As long as the `ROWID` is valid when a driver tries to send an `UPDATE` or `DELETE` operation to the database, the operation will be run.

The driver will not report any changes made by another committed transaction. Any conflicts are silently ignored and your changes will overwrite the previous changes.

To avoid such conflicts, use the Oracle `FOR UPDATE` feature when running the query that produces the result set. This will avoid conflicts, but will also prevent simultaneous access to the data. Only a single write lock can be held concurrently on a data item.

19.4 Row Fetch Size

By default, when Oracle JDBC runs a query, it retrieves a result set of 10 rows at a time from the database cursor. This is the default Oracle row fetch size value. You can change the number of rows retrieved with each trip to the database cursor by changing the row fetch size value.

Standard JDBC also enables you to specify the number of rows fetched with each database round-trip for a query, and this number is referred to as the fetch size. In Oracle JDBC, the row-prefetch value is used as the default fetch size in a statement object. Setting the fetch size overrides the row-prefetch setting and affects subsequent queries run through that statement object.

Fetch size is also used in a result set. When the statement object run a query, the fetch size of the statement object is passed to the result set object produced by the query. However, you can also set the fetch size in the result set object to override the statement fetch size that was passed to it.

> **Note**
>
> Changes made to the fetch size of a statement object after a result set is produced will have no affect on that result set.

The result set fetch size, either set explicitly, or by default equal to the statement fetch size that was passed to it, determines the number of rows that are retrieved in any subsequent trips to the database for that result set. This includes any trips that are still required to complete the original query, as well as any refetching of data into the result set. Data can be refetched, either explicitly or implicitly, to update a scroll-sensitive or scroll-insensitive/updatable result set.

19.4.1 Setting the Fetch Size

The following methods are available in all `Statement`, `PreparedStatement`, `CallableStatement`, and `ResultSet` objects for setting and getting the fetch size:

- `void setFetchSize(int rows) throws SQLException`
- `int getFetchSize() throws SQLException`

To set the fetch size for a query, call `setFetchSize` on the statement object prior to running the query. If you set the fetch size to N, then N rows are fetched with each trip to the database.

After you have run the query, you can call `setFetchSize` on the result set object to override the statement object fetch size that was passed to it. This will affect any subsequent trips to the

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database to get more rows for the original query, as well as affecting any later refetching of rows.

19.4.2 Presetting the Fetch Direction

The standard JDBC enables to pre-specify the direction, known as the fetch direction, for use in processing a result set. This allows the JDBC driver to optimize its processing. The following result set methods are specified:

- `void setFetchDirection(int direction) throws SQLException`
- `int getFetchDirection() throws SQLException`

Oracle JDBC drivers support only the forward preset value, which you can specify by entering the `ResultSet.FETCH_FORWARD` static constant value.

The values `ResultSet.FETCH_REVERSE` and `ResultSet.FETCH_UNKNOWN` are not supported. Attempting to specify them causes a SQL warning, and the settings are ignored.

19.5 About Refetching Rows

The result set `refreshRow` method is supported for some types of result sets for refetching data. This consists of going back to the database to re-obtain the database rows that correspond to *n* rows in the result set, starting with the current row, where *n* is the fetch size. This lets you see the latest updates to the database that were made outside of your result set, subject to the isolation level of the enclosing transaction.

Because refetching re-obtains only rows that correspond to rows already in your result set, it does nothing about rows that have been inserted or deleted in the database since the original query. It ignores rows that have been inserted, and rows will remain in your result set even after the corresponding rows have been deleted from the database. When there is an attempt to refetch a row that has been deleted in the database, the corresponding row in the result set will maintain its original values.

> **Note**
>
> If you declare a `TYPE_SCROLL_SENSITIVE` Result Set based on a query with certain criteria and then externally update the row so that the column values no longer match the query criteria, the driver behaves as if the row has been deleted from the database and the row is not retrieved by the query issued. So, you do not see the updates to the particular row when you call the `refreshRow` method.

Following is the signature of the `refreshRow` method:

```
void refreshRow() throws SQLException
```

You must be at a valid current row when you call this method, not outside the row bounds and not at the insert-row.

The `refreshRow` method is supported for the following result set categories:

- scroll-sensitive/read-only
- scroll-sensitive/updatable
- scroll-insensitive/updatable

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> **Note**
>
> Scroll-sensitive result set functionality is implemented through implicit calls to `refreshRow`.

19.6 About Viewing Database Changes Made Internally and Externally

This section discusses the ability of a result set to view the following:

- Own changes of the result set, referred to as internal changes
- Changes made from elsewhere, either from your own transaction outside the result set, or from other committed transactions, referred to as external changes

> **Note**
>
> External changes are referred to as other's changes in the standard JDBC specification.

This section covers the following topics:

- Visibility versus Detection of External Changes
- Summary of Visibility of Internal and External Changes
- Oracle Implementation of Scroll-Sensitive Result Sets

19.6.1 Visibility versus Detection of External Changes

Regarding the changes made to an underlying database by external sources, there are two similar but distinct concepts with respect to visibility of the changes from your local result set:

- Visibility of changes
- Detection of changes

A "visible" change means that when you look at a row in the result set, you can see new data values from changes made by external sources, to the corresponding row in the database.

A "detected" change, however, means that the result set is aware that this is a new value since the result set was first populated.

Even when an Oracle result set sees new data, as with an external `UPDATE` in a scroll-sensitive result set, it has no awareness that this data has changed since the result set was populated. Such changes are not detected.

19.6.2 Summary of Visibility of Internal and External Changes

Table 19-1 summarizes how a result set object in the Oracle JDBC implementation can see changes made internally through the result set itself, and changes made externally to the underlying database from elsewhere in your transaction or from other committed transactions.

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Table 19-1 Visibility of Internal and External Changes for Oracle JDBC

Result Set Type	Can See Internal DELETE?	Can See Internal UPDATE?	Can See Internal INSERT?	Can See External DELETE?	Can See External UPDATE?	Can See External INSERT?
forward-only	no	yes	no	no	no	no
scroll-sensitive	yes	yes	no	no	yes	no
scroll-insensitive	yes	yes	no	no	no	no

Note

- Remember that explicit use of the `refreshRow` method, is distinct from the concept of visibility of external changes.
- Remember that even when external changes are visible, as with `UPDATE` operations underlying a scroll-sensitive result set, they are not detected. The result set `rowDeleted`, `rowUpdated`, and `rowInserted` methods always return `false`.

19.6.3 Oracle Implementation of Scroll-Sensitive Result Sets

The Oracle implementation of scroll-sensitive result sets involves the concept of a window, with a window size that is based on the fetch size. The window size affects how often rows are updated in the result set.

Once you establish a current row by moving to a specified row, the window consists of the *n* rows in the result set starting with that row, where *n* is the fetch size being used by the result set. Note that there is no current row, and therefore no window, when a result set is first created. The default position is before the first row, which is not a valid current row.

As you move from row to row, the window remains unchanged as long as the current row stays within that window. However, once you move to a new current row outside the window, you redefine the window to be the N rows starting with the new current row.

Whenever the window is redefined, the N rows in the database corresponding to the rows in the new window are automatically refetched through an implicit call to the `refreshRow` method, thereby updating the data throughout the new window.

So external updates are not instantaneously visible in a scroll-sensitive result set. They are only visible after the automatic refetches just described.

Note

This kind of refetching is not a highly efficient or optimized methodology and it has significant performance concerns. Consider carefully before using scroll-sensitive result sets as currently implemented. There is also a significant trade-off between sensitivity and performance. The most sensitive result set is one with a fetch size of 1, which would result in the new current row being refetched every time you move between rows. However, this would have a significant impact on the performance of your application.

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20

JDBC RowSets

This chapter contains the following sections:

- Overview of JDBC RowSets
- About CachedRowSet
- About JdbcRowSet
- About WebRowSet
- About FilteredRowSet
- About JoinRowSet

20.1 Overview of JDBC RowSets

A RowSet is an object that encapsulates a set of rows from either Java Database Connectivity (JDBC) result sets or tabular data sources. RowSets support component-based development models like JavaBeans, with a standard set of properties and an event notification mechanism.

The JSR-114 specification includes implementation details for five types of RowSet:

- `CachedRowSet`
- `JdbcRowSet`
- `WebRowSet`
- `FilteredRowSet`
- `JoinRowSet`

Oracle JDBC supports all five types of RowSets through the interfaces and classes present in the `oracle.jdbc.rowset` package. RowSets support is uniform across all Oracle JDBC driver types. The standard Oracle JDBC Java Archive (JAR) files contain the `oracle.jdbc.rowset` package.

To use the Oracle RowSet implementations, you need to import either the entire `oracle.jdbc.rowset` package or specific classes and interfaces from the package for the required RowSet type. For client-side usage, you also need to include the standard Oracle JAR files like `ojdbc8.jar`, `ojdbc11.jar`, or `ojdbc17.jar` in the `CLASSPATH` environment variable.

This section covers the following topics:

- RowSet Properties
- Events and Event Listeners
- Command Parameters and Command Execution
- About Traversing RowSets

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20.1.1 RowSet Properties

The `javax.sql.RowSet` interface provides a set of JavaBeans properties that can be altered to access the data in the data source through a single interface. Example of properties are connection string, user name, password, type of connection, and the query string.

> **See Also**
>
> The Java 2 Platform, Standard Edition (J2SE) Javadoc for a complete list of properties and property descriptions at http://docs.oracle.com/javase/1.5.0/docs/api/javax/sql/RowSet.html

The interface provides standard accessor methods for setting and retrieving the property values. The following code illustrates setting some of the `RowSet` properties:

```
...
rowset.setUrl("jdbc:oracle:oci:@");
rowset.setUsername("HR");
rowset.setPassword("hr");
rowset.setCommand("SELECT employee_id, first_name, last_name, salary FROM employees");
...
```

In this example, the URL, user name, password, and SQL query are set as the `RowSet` properties to retrieve the employee number, employee name, and salary of all the employees into the `RowSet` object.

20.1.2 Events and Event Listeners

RowSets support JavaBeans events. The following types of events are supported by the `RowSet` interface:

- `cursorMoved`

  This event is generated whenever there is a cursor movement. For example, when the `next` or `previous` method is called.

- `rowChanged`

  This event is generated when a row is inserted, updated, or deleted from the RowSet.

- `rowSetChanged`

  This event is generated when the whole RowSet is created or changed. For example, when the `execute` method is called.

An application component can implement a RowSet listener to listen to these RowSet events and perform desired operations when the event occurs. Application components, which are interested in these events, must implement the standard `javax.sql.RowSetListener` interface and register such listener objects with a `RowSet` object. A listener can be registered using the `RowSet.addRowSetListener` method and unregistered using the `RowSet.removeRowSetListener` method. Multiple listeners can be registered with the same `RowSet` object.

The following code illustrates the registration of a RowSet listener:

```
 ...
 MyRowSetListener rowsetListener = new MyRowSetListener ();
```


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```
// adding a rowset listener
rowset.addRowSetListener (rowsetListener);
...
```

The following code illustrates a listener implementation:

```
public class MyRowSetListener implements RowSetListener
 {
   public void cursorMoved(RowSetEvent event)
   {
     // action on cursor movement
   }

   public void rowChanged(RowSetEvent event)
   {
     // action on change of row
   }

   public void rowSetChanged(RowSetEvent event)
   {
     // action on changing of rowset
   }
 }// end of class MyRowSetListener
```

Applications that need to handle only selected events can implement only the required event handling methods by using the `oracle.jdbc.rowset.OracleRowSetListenerAdapter` class, which is an abstract class with empty implementation for all the event handling methods. In the following code, only the `rowSetChanged` event is handled, while the remaining events are not handled by the application:

```
...
rowset.addRowSetListener(new oracle.jdbc.rowset.OracleRowSetListenerAdapter ()
   {
     public void rowSetChanged(RowSetEvent event)
     {
       // your action for rowSetChanged
     }
   }
 );
...
```

20.1.3 Command Parameters and Command Execution

The `command` property of a `RowSet` object typically represents a SQL query string, which when processed would populate the `RowSet` object with actual data. Like in regular JDBC processing, this query string can take input or bind parameters. The `javax.sql.RowSet` interface also provides methods for setting input parameters to this SQL query. After the required input parameters are set, the SQL query can be processed to populate the `RowSet` object with data from the underlying data source. The following code illustrates this simple sequence:

```
...
  rowset.setCommand("SELECT first_name, last_name, salary FROM employees WHERE
employee_id = ?");
  // setting the employee number input parameter for employee named "Douglas"
  rowset.setInt(1, 199);
  rowset.execute();
  ...
```

In the preceding example, the employee number 199 is set as the input or bind parameter for the SQL query specified in the `command` property of the `RowSet` object. When the SQL query is

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processed, the RowSet object is filled with the employee name and salary information of the employee whose employee number is 199.

20.1.4 About Traversing RowSets

The javax.sql.RowSet interface extends the java.sql.ResultSet interface. The RowSet interface, therefore, provides cursor movement and positioning methods, which are inherited from the ResultSet interface, for traversing through data in a RowSet object. Some of the inherited methods are absolute, beforeFirst, afterLast, next, and previous.

The RowSet interface can be used just like a ResultSet interface for retrieving and updating data. The RowSet interface provides an optional way to implement a scrollable and updatable result set. All the fields and methods provided by the ResultSet interface are implemented in RowSet.

> **Note**
>
> The Oracle implementation of ResultSet provides the scrollable and updatable properties of the java.sql.ResultSet interface.

The following code illustrates how to scroll through a RowSet:

```
/**
 *  Scrolling forward, and printing the empno in
 *  the order in which it was fetched.
 */
...
rowset.setCommand("SELECT empno, ename, sal FROM emp");
rowset.execute();
...
// going to the first row of the rowset
rowset.beforeFirst ();
while (rowset.next ())
  System.out.println ("empno: " +rowset.getInt (1));
```

In the preceding code, the cursor position is initialized to the position before the first row of the RowSet by the beforeFirst method. The rows are retrieved in forward direction using the next method.

The following code illustrates how to scroll through a RowSet in the reverse direction:

```
/**
 *  Scrolling backward, and printing the empno in
 *  the reverse order as it was fetched.
 */
//going to the last row of the rowset
rowset.afterLast ();
while (rowset.previous ())
  System.out.println ("empno: " +rowset.getInt (1));
```

In the preceding code, the cursor position is initialized to the position after the last row of the RowSet. The rows are retrieved in reverse direction using the previous method of RowSet.

Inserting, updating, and deleting rows are supported by the Row Set feature as they are in the Result Set feature. In order to make the Row Set updatable, you must call the setReadOnly(false) and acceptChanges methods.

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The following code illustrates the insertion of a row at the fifth position of a Row Set:

```
...
/**
  * Make rowset updatable
  */
rowset.setReadOnly (false);
/**
 * Inserting a row in the 5th position of the rowset.
 */
// moving the cursor to the 5th position in the rowset
if (rowset.absolute(5))
{
  rowset.moveToInsertRow ();
  rowset.updateInt (1, 193);
  rowset.updateString (2, "Smith");
  rowset.updateInt (3, 7200);

  // inserting a row in the rowset
  rowset.insertRow ();

  // Synchronizing the data in RowSet with that in the database.
  rowset.acceptChanges ();
}
...
```

In the preceding code, a call to the `absolute` method with a parameter `5` takes the cursor to the fifth position of the RowSet and a call to the `moveToInsertRow` method creates a place for the insertion of a new row into the RowSet. The `update`*`XXX`* methods are used to update the newly created row. When all the columns of the row are updated, the `insertRow` is called to update the RowSet. The changes are committed through `acceptChanges` method.

20.2 About the CachedRowSet Interface

A `CachedRowSet` is a RowSet in which the rows are cached and the RowSet is disconnected, that is, it does not maintain an active connection to the database.

The `oracle.jdbc.rowset.OracleCachedRowSet` class is the Oracle implementation of `CachedRowSet`. It can interoperate with the standard reference implementation. The `OracleCachedRowSet` class, which is present in the `ojdbc8.jar`, `ojdbc11.jar`, and `ojdbc17.jar` files, implements the standard JSR-114 interface `javax.sql.rowset.CachedRowSet`.

In the following code, an `OracleCachedRowSet` object is created and the connection URL, user name, password, and the SQL query for the `RowSet` object is set as properties. The `RowSet` object is populated using the `execute` method. After the `execute` method has been processed, the `RowSet` object can be used as a `java.sql.ResultSet` object to retrieve, scroll, insert, delete, or update data.

```
...
RowSet rowset = new OracleCachedRowSet();
rowset.setUrl("jdbc:oracle:oci:@");
rowset.setUsername("HR");
rowset.setPassword("hr");
rowset.setCommand("SELECT employee_id, first_name, last_name, salary FROM employees");
rowset.execute();
while (rowset.next ())
{
  System.out.println("employee_id: " +rowset.getInt (1));
  System.out.println("first_name: " +rowset.getString (2));
```


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```
  System.out.println("last_name: " +rowset.getString (3));
  System.out.println("sal: "   +rowset.getInt (4));
}
...
```

To populate a `CachedRowSet` object with a query, complete the following steps:

1. Instantiate `OracleCachedRowSet`.
2. Set the `Url`, which is the connection URL, `Username`, `Password`, and `Command`, which is the query string, properties for the `RowSet` object. You can also set the connection type, but it is optional.
3. Call the `execute` method to populate the `CachedRowSet` object. Calling `execute` runs the query set as a property on this RowSet.

```
    OracleCachedRowSet rowset = new OracleCachedRowSet ();
    rowset.setUrl ("jdbc:oracle:oci:@");
    rowset.setUsername ("HR");
    rowset.setPassword ("hr");
    rowset.setCommand ("SELECT employee_id, first_name, last_name, salary FROM
employees");
    rowset.execute ();
```

A `CachedRowSet` object can be populated with an existing `ResultSet` object, using the `populate` method. To do so, complete the following steps:

1. Instantiate `OracleCachedRowSet`.
2. Pass the already available `ResultSet` object to the `populate` method to populate the `RowSet` object.

```
    // Executing a query to get the ResultSet object.
    ResultSet rset = pstmt.executeQuery ();

    OracleCachedRowSet rowset = new OracleCachedRowSet ();
    // the obtained ResultSet object is passed to the populate method
    // to populate the data in the rowset object.
    rowset.populate (rset);
```

In the preceding example, a `ResultSet` object is obtained by running a query and the retrieved `ResultSet` object is passed to the `populate` method of the `CachedRowSet` object to populate the contents of the result set into the CachedRowSet.

> **Note**
>
> Connection properties, like transaction isolation or the concurrency mode of the result set, and the bind properties cannot be set in the case where a pre-existent `ResultSet` object is used to populate the `CachedRowSet` object, because the connection or result set on which the property applies would have already been created.

The following code illustrates how an `OracleCachedRowSet` object is serialized to a file and then retrieved:

```
// writing the serialized OracleCachedRowSet object
{
  FileOutputStream fileOutputStream = new FileOutputStream("emp_tab.dmp");
```


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```
  ObjectOutputStream ostream = new ObjectOutputStream(fileOutputStream);
  ostream.writeObject(rowset);
  ostream.close();
  fileOutputStream.close();
}

// reading the serialized OracleCachedRowSet object
{
  FileInputStream fileInputStream = new FileInputStream("emp_tab.dmp");
  ObjectInputStream istream = new ObjectInputStream(fileInputStream);
  RowSet rowset1 = (RowSet) istream.readObject();
  istream.close();
  fileInputStream.close();
}
```

In the preceding code, a `FileOutputStream` object is opened for an `emp_tab.dmp` file, and the populated `OracleCachedRowSet` object is written to the file using `ObjectOutputStream`. The serialized `OracleCachedRowSet` object is retrieved using the `FileInputStream` and `ObjectInputStream` objects.

`OracleCachedRowSet` takes care of the serialization of non-serializable form of data like `InputStream`, `OutputStream`, binary large objects (BLOBs), and character large objects (CLOBs). `OracleCachedRowSets` also implements metadata of its own, which could be obtained without any extra server round-trip. The following code illustrates how you can obtain metadata for the RowSet:

```
...
ResultSetMetaData metaData = rowset.getMetaData();
int maxCol = metaData.getColumnCount();
for (int i = 1; i <= maxCol; ++i)
   System.out.println("Column (" + i +") " + metaData.getColumnName(i));
...
```

Because the `OracleCachedRowSet` class is serializable, it can be passed across a network or between Java Virtual Machines (JVMs), as done in Remote Method Invocation (RMI). Once the `OracleCachedRowSet` class is populated, it can move around any JVM, or any environment that does not have JDBC drivers. Committing the data in the RowSet requires the presence of JDBC drivers.

The complete process of retrieving the data and populating it in the `OracleCachedRowSet` class is performed on the server and the populated RowSet is passed on to the client using suitable architectures like RMI or Enterprise Java Beans (EJB). The client would be able to perform all the operations like retrieving, scrolling, inserting, updating, and deleting on the RowSet without any connection to the database. Whenever data is committed to the database, the `acceptChanges` method is called, which synchronizes the data in the RowSet to that in the database. This method makes use of JDBC drivers, which require the JVM environment to contain JDBC implementation. This architecture would be suitable for systems involving a Thin client like a Personal Digital Assistant (PDA).

After populating the `CachedRowSet` object, it can be used as a `ResultSet` object or any other object, which can be passed over the network using RMI or any other suitable architecture.

Some of the other key-features of CachedRowSet are the following:

- Cloning a RowSet
- Creating a copy of a RowSet
- Creating a shared copy of a RowSet

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CachedRowSet Constraints

All the constraints that apply to an updatable result set are applicable here, except serialization, because `OracleCachedRowSet` is serializable. The SQL query has the following constraints:

- References only a single table in the database
- Contains no join operations
- Selects the primary key of the table it references

In addition, a SQL query should also satisfy the following conditions, if new rows are to be inserted:

- Selects all non-nullable columns in the underlying table
- Selects all columns that do not have a default value

> **Note**
>
> The `CachedRowSet` cannot hold a large quantity of data, because all the data is cached in memory. Oracle, therefore, recommends against using `OracleCachedRowSet` with queries that could potentially return a large volume of data.

Connection properties like, transaction isolation and concurrency mode of the result set, cannot be set after populating the RowSet, because the properties cannot be applied to the connection after retrieving the data from the same.

20.3 About the JdbcRowSet Interface

A `JdbcRowSet` is a RowSet that wraps around a `ResultSet` object. It is a connected RowSet that provides JDBC interfaces in the form of a Java Bean interface.

The Oracle implementation of `JdbcRowSet` is `oracle.jdbc.rowset.OracleJDBCRowSet`. The `Atherosclerosis` class, which is present in the `ojdbc8.jar`, `ojdbc11.jar`, and `ojdbc17.jar` files, implements the standard JSR-114 interface `javax.sql.rowset.JdbcRowSet`.

Table 20-1 shows how the `JdbcRowSet` interface differs from `CachedRowSet` interface.

Table 20-1 Comparison Between the JDBC Row Sets and the Cached Row Sets

RowSet Type	Serializable	Connected to Database	Movable Across JVMs	Synchronization of data to database	Presence of JDBC Drivers
JDBC	Yes	Yes	No	No	Yes
Cached	Yes	No	Yes	Yes	No

`JdbcRowSet` is a connected RowSet, which has a live connection to the database and all the calls on the `JdbcRowSet` are percolated to the mapping call in the JDBC connection, statement, or result set. A `CachedRowSet` does not have any connection to the database open.

`JdbcRowSet` requires the presence of JDBC drivers unlike a `CachedRowSet`, which does not require JDBC drivers during manipulation. However, both `JdbcRowSet` and `CachedRowSet`

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require JDBC drivers during population of the RowSet and while committing the changes of the RowSet.

The following code illustrates how a `JdbcRowSet` is used:

```
...
RowSet rowset = new Atherosclerosis();
rowset.setUrl("java:oracle:oci:@");
rowset.setUsername("HR");
rowset.setPassword("hr");
rowset.setCommand("SELECT empno, ename, sal FROM emp");
rowset.execute();
while (rowset.next())
{
  System.out.println("empno: " + rowset.getInt(1));
  System.out.println("ename: " + rowset.getString(2));
  System.out.println("sal: " + rowset.getInt(3));
}
...
```

In the preceding example, the connection URL, user name, password, and SQL query are set as properties of the `RowSet` object, the SQL query is processed using the `execute` method, and the rows are retrieved and printed by traversing through the data populated in the `RowSet` object.

20.4 About the WebRowSet Interface

A `WebRowSet` is an extension to `CachedRowSet`. It represents a set of fetched rows or tabular data that can be passed between tiers and components in a way such that no active connections with the data source need to be maintained.

The `WebRowSet` interface provides support for the production and consumption of result sets and their synchronization with the data source, both in Extensible Markup Language (XML) format and in disconnected fashion. This allows result sets to be shipped across tiers and over Internet protocols.

The Oracle implementation of `WebRowSet` is `oracle.jdbc.rowset.OracleWebRowSet`. This class, which is in the `ojdbc8.jar`, `ojdbc11.jar`, and `ojdbc17.jar` files, implements the standard JSR-114 interface `javax.sql.rowset.WebRowSet`. This class also extends the `oracle.jdbc.rowset.OracleCachedRowSet` class. Besides the methods available in `OracleCachedRowSet`, the `OracleWebRowSet` class provides the following methods:

- `public OracleWebRowSet() throws SQLException`

  This is the constructor for creating an `OracleWebRowSet` object, which is initialized with the default values for an `OracleCachedRowSet` object, a default `OracleWebRowSetXmlReader`, and a default `OracleWebRowSetXmlWriter`.

- `public void writeXml(java.io.Writer writer) throws SQLException`
  `public void writeXml(java.io.OutputStream ostream) throws SQLException`

  These methods write the `OracleWebRowSet` object to the supplied `Writer` or `OutputStream` object in the XML format that conforms to the JSR-114 XML schema. In addition to the RowSet data, the properties and metadata of the RowSet are written.

- `public void writeXml(ResultSet rset, java.io.Writer writer) throws SQLException`
  `public void writeXml(ResultSet rset, java.io.OutputStream ostream) throws SQLException`

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These methods create an `OracleWebRowSet` object, populate it with the data in the given `ResultSet` object, and write it to the supplied `Writer` or `OutputStream` object in the XML format that conforms to the JSR-114 XML schema.

- `public void readXml(java.io.Reader reader) throws SQLException`
  `public void readXml(java.io.InputStream istream) throws SQLException`

  These methods read the `OracleWebRowSet` object in the XML format according to its JSR-114 XML schema, using the supplied `Reader` or `InsputStream` object.

The Oracle WebRowSet implementation supports Java API for XML Processing (JAXP) 1.2. Both Simple API for XML (SAX) 2.0 and Document Object Model (DOM) JAXP-conforming XML parsers are supported. It follows the current JSR-114 W3C XML schema for WebRowSet.

Applications that use the `readXml(...)` methods should set one of the following two standard JAXP system properties before calling the methods:

- `javax.xml.parsers.SAXParserFactory`

  This property is for a SAX parser.

- `javax.xml.parsers.DocumentBuilderFactory`

  This property is for a DOM parser.

The following code illustrates the use of `OracleWebRowSet` for both writing and reading in XML format:

```
import java.sql.*;
import java.io.*;
import oracle.jdbc.rowset.*;

...
String url = "jdbc:oracle:oci8:@";

Connection conn = DriverManager.getConnection(url,"HR","hr");
Statement stmt = conn.createStatement();
ResultSet rset = stmt.executeQuery("select * from employees");

// Create an OracleWebRowSet object and populate it with the ResultSet object
OracleWebRowSet wset = new OracleWebRowSet();
wset.populate(rset);

try
{
  // Create a java.io.Writer object
  FileWriter out = new FileWriter("xml.out");

  // Now generate the XML and write it out
  wset.writeXml(out);
}
catch (IOException exc)
{
  System.out.println("Couldn't construct a FileWriter");
}
System.out.println("XML output file generated.");

// Create a new OracleWebRowSet for reading from XML input
OracleWebRowSet wset2 = new OracleWebRowSet();

// Use Oracle JAXP SAX parser
System.setProperty("javax.xml.parsers.SAXParserFactory","oracle.xml.jaxp.JXSAXParserFacto
ry");
```


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```
try
{
  // Use the preceding output file as input
  FileReader fr = new FileReader("xml.out");

  // Now read XML stream from the FileReader
  wset2.readXml(fr);
}
catch (IOException exc)
{
  System.out.println("Couldn't construct a FileReader");
}
...
```

> **Note**
>
> The preceding code uses the Oracle SAX XML parser, which supports schema validation.

20.5 About the FilteredRowSet Interface

A `FilteredRowSet` is an extension to `WebRowSet` that provides programmatic support for filtering its content. This enables you to avoid the overhead of supplying a query and the processing involved. The Oracle implementation of `FilteredRowSet` is `oracle.jdbc.rowset.OracleFilteredRowSet`. The `OracleFilteredRowSet` class, which is present in the `ojdbc11.jar` and `ojdbc17.jar` files, implements the standard JSR-114 interface `javax.sql.rowset.FilteredRowSet`.

The `OracleFilteredRowSet` class defines the following new methods:

- `public Predicate getFilter();`

  This method returns a `Predicate` object that defines the filtering criteria active on the `OracleFilteredRowSet` object.

- `public void setFilter(Predicate p) throws SQLException;`

  This method takes a `Predicate` object as a parameter. The `Predicate` object defines the filtering criteria to be applied on the `OracleFilteredRowSet` object. The methods throws a `SQLException` exception.

The predicate set on an `OracleFilteredRowSet` object defines a filtering criteria that is applied to all the rows in the object to obtain the set of visible rows. The predicate also defines the criteria for inserting, deleting, and modifying rows. The set filtering criteria acts as a gating mechanism for all views and updates to the `OracleFilteredRowSet` object. Any attempt to update the `OracleFilteredRowSet` object, which violates the filtering criteria, throws a `SQLException` exception.

The filtering criteria set on an `OracleFilteredRowSet` object can be modified by applying a new `Predicate` object. The new criteria is immediately applied on the object, and all further views and updates must adhere to this new criteria. A new filtering criteria can be applied only if there are no reference to the `OracleFilteredRowSet` object.

Rows that fall outside of the filtering criteria set on the object cannot be modified until the filtering criteria is removed or a new filtering criteria is applied. Also, only the rows that fall

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within the bounds of the filtering criteria will be synchronized with the data source, if an attempt is made to persist the object.

The following code example illustrates the use of OracleFilteredRowSet. Assume a table, `test_table`, with two `NUMBER` columns, `col1` and `col2`. The code retrieves those rows from the table that have value of `col1` between `50` and `100` and value of `col2` between `100` and `200`.

The predicate defining the filtering criteria is as follows:

```
public class PredicateImpl implements Predicate
{
  private int low[];
  private int high[];
  private int columnIndexes[];

  public PredicateImpl(int[] lo, int[] hi, int[] indexes)
  {
    low = lo;
    high = hi;
    columnIndexes = indexes;
  }

  public boolean evaluate(RowSet rs)
  {
    boolean result = true;
    for (int i = 0; i < columnIndexes.length; i++)
    {
      int columnValue = rs.getInt(columnIndexes[i]);
      if (columnValue < low[i] || columnValue > high[i])
        result = false;
    }
    return result;
  }

// the other two evaluate(...) methods simply return true

}
```

The predicate defined in the preceding code is used for filtering content in an `OracleFilteredRowSet` object, as follows:

```
...
OracleFilteredRowSet ofrs = new OracleFilteredRowSet();
int low[] = {50, 100};
int high[] = {100, 200};
int indexes[] = {1, 2};
ofrs.setCommand("select col1, col2 from test_table");

// set other properties on ofrs like usr/pwd ...
...
ofrs.execute();
ofrs.setPredicate(new PredicateImpl(low, high, indexes));

// this will only get rows with col1 in (50,100) and col2 in (100,200)
while (ofrs.next()) {...}
...
```

20.6 About the JoinRowSet Interface

A `JoinRowSet` is an extension to `WebRowSet` that consists of related data from different RowSets.

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There is no standard way to establish a SQL JOIN between disconnected RowSets without connecting to the data source. A JoinRowSet addresses this issue. The Oracle implementation of JoinRowSet is the oracle.jdbc.rowset.OracleJoinRowSet class. This class, which is in the ojdbc11.jar and ojdbc17.jar files, implements the standard JSR-114 interface javax.sql.rowset.JoinRowSet.

Any number of RowSet objects, which implement the Joinable interface, can be added to a JoinRowSet object, provided they can be related in a SQL JOIN. All five types of RowSet support the Joinable interface. The Joinable interface provides methods for specifying the columns based on which the JOIN will be performed, that is, the match columns.

A match column can be specified in the following ways:

- Using the setMatchColumn method

  This method is defined in the Joinable interface. It is the only method that can be used to set the match column before a RowSet object is added to a JoinRowSet object. This method can also be used to reset the match column at any time.

- Using the addRowSet method

  This is an overloaded method in JoinRowSet. Four of the five implementations of this method take a match column as a parameter. These four methods can be used to set or reset a match column at the time a RowSet object is being added to a JoinRowSet object.

In addition to the inherited methods, OracleJoinRowSet provides the following methods:

- ```
  public void addRowSet(Joinable joinable) throws SQLException;
  public void addRowSet(RowSet rowSet, int i) throws SQLException;
  public void addRowSet(RowSet rowSet, String s) throws SQLException;
  public void addRowSet(RowSet arowSet[], int an[]) throws SQLException;
  public void addRowSet(RowSet arowSet[], String as[]) throws SQLException;
  ```

  These methods are used to add a RowSet object to the OracleJoinRowSet object. You can pass one or more RowSet objects to be added to the OracleJoinRowSet object. You can also pass names or indexes of one or more columns, which need to be set as match column.

- ```
  public Collection getRowSets() throws SQLException;
  ```

  This method retrieves the RowSet objects added to the OracleJoinRowSet object. The method returns a java.util.Collection object that contains the RowSet objects.

- ```
  public String[] getRowSetNames() throws SQLException;
  ```

  This method returns a String array containing the names of the RowSet objects that are added to the OracleJoinRowSet object.

- ```
  public boolean supportsCrossJoin();
  public boolean supportsFullJoin();
  public boolean supportsInnerJoin();
  public boolean supportsLeftOuterJoin();
  public boolean supportsRightOuterJoin();
  ```

  These methods return a boolean value indicating whether the OracleJoinRowSet object supports the corresponding JOIN type.

- ```
  public void setJoinType(int i) throws SQLException;
  ```

  This method is used to set the JOIN type on the OracleJoinRowSet object. It takes an integer constant as defined in the javax.sql.rowset.JoinRowSet interface that specifies the JOIN type.

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  ```

- `public int getJoinType() throws SQLException;`

  This method returns an integer value that indicates the `JOIN` type set on the `OracleJoinRowSet` object. This method throws a `SQLException` exception.

- `public CachedRowSet toCachedRowSet() throws SQLException;`

  This method creates a `CachedRowSet` object containing the data in the `OracleJoinRowSet` object.

- `public String getWhereClause() throws SQLException;`

  This method returns a String containing the SQL-like description of the `WHERE` clause used in the `OracleJoinRowSet` object. This methods throws a `SQLException` exception.

The following code illustrates how `OracleJoinRowSet` is used to perform an inner join on two RowSets, whose data come from two different tables. The resulting RowSet contains data as if they were the result of an inner join on these two tables. Assume that there are two tables, an `Order` table with two `NUMBER` columns `Order_id` and `Person_id`, and a `Person` table with a `NUMBER` column `Person_id` and a `VARCHAR2` column `Name`.

```
...
// RowSet holding data from table Order
OracleCachedRowSet ocrsOrder = new OracleCachedRowSet();
...
ocrsOrder.setCommand("select order_id, person_id from order");
...
// Join on person_id column
ocrsOrder.setMatchColumn(2);
ocrsOrder.execute();

// Creating the JoinRowSet
OracleJoinRowSet ojrs = new OracleJoinRowSet();
ojrs.addRowSet(ocrsOrder);

// RowSet holding data from table Person
OracleCachedRowSet ocrsPerson = new OracleCachedRowSet();
...
ocrsPerson.setCommand("select person_id, name from person");
...
// do not set match column on this RowSet using setMatchColumn().
//use addRowSet() to set match column
ocrsPerson.execute();

// Join on person_id column, in another way
ojrs.addRowSet(ocrsPerson, 1);

// now we can go the JoinRowSet as usual
ojrs.beforeFirst();
while (ojrs.next())
System.out.println("order id = " + ojrs.getInt(1) + ", " + "person id = " +
ojrs.getInt(2) + ", " + "person's name = " + ojrs.getString(3));
...
```


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21
Globalization Support

The Oracle Java Database Connectivity (JDBC) drivers provide globalization support, formerly known as National Language Support (NLS). Globalization support enables you to retrieve data or insert data into a database in any character set that Oracle supports. If the clients and the server use different character sets, then the driver provides the support to perform the conversions between the database character set and the client character set.

This chapter contains the following sections:

- About Providing Globalization Support
- NCHAR_ NVARCHAR2_ NCLOB and the defaultNChar Property
- New Methods for National Character Set Type Data in JDK 6

> **Note**
>
> - Starting from Oracle Database 10*g*, the `NLS_LANG` variable is no longer part of the JDBC globalization mechanism. The JDBC driver does not check NLS environment. So, setting it has no effect.
> - The JDBC server-side internal driver provides complete globalization support and does not require any globalization extension files.
> - JDBC 4.0 includes methods for reading and writing national character set values. You should use these methods when using JSE 6 or later.

Related Topics

- Oracle Character Data Types Support
- *Oracle AI Database Globalization Support Guide*

21.1 About Providing Globalization Support

The basic Java Archive (JAR) files, `ojdbc11.jar` and `ojdbc17.jar`, contain all the necessary classes to provide complete globalization support.

This support includes the following:

- Oracle character sets for `CHAR`, `VARCHAR`, `LONGVARCHAR`, or `CLOB` data that is not being retrieved or inserted as a data member of an Oracle object or collection type.
- `CHAR` or `VARCHAR` data members of object and collection for the character sets `US7ASCII`, `WE8DEC`, `WE8ISO8859P1`, `WE8MSWIN1252`, and `UTF8`.

To use any other character sets in `CHAR` or `VARCHAR` data members of objects or collections, you must include `orai18n.jar` in the `CLASSPATH` environment variable:

```
ORACLE_HOME/jlib/orai18n.jar
```


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> **Note**
>
> Previous releases depended on the `nls_charset12.zip` file. This file is now obsolete.

Compressing orai18n.jar

The `orai18n.jar` file contains many important character set and globalization support files. You can reduce the size of `orai18n.jar` using the built-in customization tool, as follows:

```
java -jar orai18n.jar -custom-charsets-jar [jar/zip_filename] -charset characterset_name
[characterset_name ...]
```

For example, if you want to create a custom character set file, `custom_orai18n_ja.jar`, that includes the JA16SJIS and JA16EUC character sets, then issue the following command:

```
$ java -jar orai18n.jar -custom-charsets-jar custom_orai18n_ja.jar -charset JA16SJIS
JA16EUC
```

The output of the command is as follows:

```
Added Character set : JA16SJIS
Added Character set : JA16EUC
```

If you do not specify a file name for your custom JAR/ZIP file, then a file with the name `jdbc_orai18n_cs.jar` is created in the current working directory. Also, for your custom JAR/ZIP file, you cannot specify a name that starts with `orai18n`.

If any invalid or unsupported character set name is specified in the command, then no output JAR/ZIP file will be created. If the custom JAR/ZIP file exists, then the file will not be updated or removed.

The custom character set JAR/ZIP does not accept any command. However, it prints the version information and the command that was used to generate the JAR/ZIP file. For example, you have `jdbc_orai18n_cs.zip`, the command that displays the information and the displayed information is as follows:

```
$ java -jar jdbc_orai18n_cs.jar
Oracle Globalization Development Kit - 12.1.X.X.X Release
This custom character set jar/zip file was created with the following command:
java -jar orai18n.jar -custom-charsets-jar jdbc_orai18n_cs.jar -charset WE8ISO8859P15
```

The limitation to the number of character sets that can be specified depends on that of the shell or command prompt of the operating system. It is certified that all supported character sets can be specified with the command.

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> **Note**
>
> If you are using a custom character set, then you need to perform the following so that JDBC supports the custom character set:
>
> 1. After creating the `.nlt` and `.nlb` files as part of the process of creating a custom character set, create `.glb` files for the newly created character set and also for the `lx0boot.nlt` file using the following command:
>
>    ```
>    java -classpath $ORACLE_HOME/jlib/orai18n.jar:$ORACLE_HOME/lib/
>    xmlparserv2.jar Ginstall -[add | a] <NLT_file_name>
>    ```
>
> 2. Add the generated files and `$ORACLE_HOME/jlib/orai18n-mappings.jar` into the `classpath` environment variable while executing the JDBC code that connects to the database with the custom character set.

21.2 NCHAR, NVARCHAR2, NCLOB and the defaultNChar Property

By default, the `oracle.jdbc.OraclePreparedStatement` interface treats the data type of all the columns in the same way as they are encoded in the database character set. However, since Oracle Database 10*g*, if you set the value of `oracle.jdbc.defaultNChar` system property to `true`, then JDBC treats all character columns as being national-language.

The default value of `defaultNChar` is false. If the value of `defaultNChar` is false, then you must call the `setFormOfUse(<column_Index>, OraclePreparedStatement.FORM_NCHAR)` method for those columns that specifically need national-language characters. For example:

```
PreparedStatement pstmt =
conn.prepareStatement("insert into TEST values(?,?,?)");
pstmt.setFormOfUse(1, OraclePreparedStatement.FORM_NCHAR);
pstmt.setString(1, myUnicodeString1); // NCHAR column
pstmt.setFormOfUse(2, OraclePreparedeStatement.FORM_NCHAR);
pstmt.setString(2, myUnicodeString2); // NVARCHAR2 column
```

If you want to set the value of `defaultNChar` to `true`, then specify the following at the command-line:

```
java -Doracle.jdbc.defaultNChar=true myApplication
```

If you prefer, then you can also specify `defaultNChar` as a connection property and access `NCHAR`, `NVARCHAR2`, or `NCLOB` data.

```
Properties props = new Properties();
props.put(OracleConnection.CONNECTION_PROPERTY_DEFAULTNCHAR, "true");
// set URL, username, password, and so on.
...
Connection conn = DriverManager.getConnection(props);
```

If the value of `defaultNChar` is `true`, then you should call the `setFormOfUse(<column_Index>, FORM_CHAR)` for columns that do not need national-language characters. For example:

```
PreparedStatement pstmt =
conn.prepareStatement("insert into TEST values(?,?,?)");
pstmt.setFormOfUse(3, OraclePreparedStatement.FORM_CHAR);
pstmt.setString(3, myString); // CHAR column
```


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> **Note**
>
> If you set the value of `defaultNChar` to `true` and then access `CHAR` columns, then the database will implicitly convert all `CHAR` data into `NCHAR`. This conversion has a substantial performance impact.

> **Note**
>
> - Always use `java.lang.String` for character data instead of `oracle.sql.CHAR`. `CHAR` is provided only for backward compatibility.
> - You can also use the `setObject` method to access national character set types, but if the `setObject` method is used, then the target data type must be specified as `Types.NCHAR`, `Types.NCLOB`, `Types.NVARCHAR`, or `Types.LONGNVARCHAR`.

> **Note**
>
> In Oracle Database, SQL strings are converted to the database character set. Therefore you need to keep in mind the following:
>
> - In Oracle Database 10*g* release 1 (10.1) and earlier releases, JDBC drivers do not support any `NCHAR` literal (n'...') containing Unicode characters that are not representable in the database character set. All Unicode characters that are not representable in the database character set get corrupted.
> - If an Oracle Database 10*g* release 2 (10.2) JDBC driver is connected to an Oracle Database 10*g* release 2 (10.2) database server, then all `NCHAR` literals (n'...') are converted to Unicode literals (u'...') and all non-ASCII characters are converted to their corresponding Unicode escape sequence. This is done automatically to prevent data corruption.
> - If an Oracle Database 10*g* release 2 (10.2) JDBC driver is connected to an Oracle Database 10*g* release 1 (10.1) or earlier database server, then `NCHAR` literals (n'...') are not converted and any character that is not representable in the database character set gets corrupted.

21.3 New Methods for National Character Set Type Data in JDK 6

JDBC 4.0 introduces support for the following four additional SQL types to access the national character set types:

- `NCHAR`
- `NVARCHAR`
- `LONGNVARCHAR`
- `NCLOB`

These types are similar to the `CHAR`, `VARCHAR`, `LONGVARCHAR`, and `CLOB` types, except that the values are encoded using the national character set. The JDBC specification uses the `String`

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class to represent `NCHAR`, `NVARCHAR`, and `LONGNVARCHAR` data, and the `NClob` class to represent `NCLOB` values.

To retrieve a national character value, an application calls one of the following methods:

- `getNString`
- `getNClob`
- `getNCharacterStream`
- `getObject`

> **Note**
>
> The `getClob` method may be used to return an `NClob` object since `NClob` implements `Clob`.

To specify a value for a parameter marker of national character type, an application calls one of the following methods:

- `setNString`
- `setNCharacterStream`
- `setNClob`
- `setObject`

> **Note**
>
> You can use the `setFormOfUse` method to specify a national character value in JDK 6. But this practice is discouraged because this method will be deprecated in future release. So, Oracle recommends you to use the methods discussed in this section.

> **See Also**
>
> If the `setObject` method is used, then the target data type must be specified as `Types.NCHAR`, `Types.NCLOB`, `Types.NVARCHAR`, or `Types.LONGNVARCHAR`.

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Part V
Performance and Scalability

This part consists of chapters that discuss the Oracle Java Database Connectivity (JDBC) features that enhance performance, such as Statement caching and Oracle Call Interface (OCI) connection pooling. It also includes a chapter that provides information about Oracle performance extensions, such as update batching and row prefetching.

Part V contains the following chapters:

- Statement and Result Set Caching
- Performance Extensions
- JDBC Reactive Extensions
- Support for Java library for Reactive Streams Ingestion
- Support for Pipelined Database Operations
- OCI Connection Pooling
- Database Resident Connection Pooling
- JDBC Support for Database Sharding
- Oracle Advanced Queuing
- Continuous Query Notification

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22

Statement and Result Set Caching

This chapter describes the benefits and use of Statement caching, an Oracle Java Database Connectivity (JDBC) extension.

> **Note**
>
> Use statement caching only when you are sure that the table structure remains the same in the database. If you alter the table structure and then reuse a statement that was created and executed before changing the table structure, then you may get an error.

This chapter contains the following sections:

- About Statement Caching
- About Using Statement Caching
- About Reusing Statements Objects
- About Result Set Caching

22.1 About Statement Caching

Statement caching improves performance by caching executable statements that are used repeatedly, such as in a loop or in a method that is called repeatedly. Starting from JDBC 3.0, JDBC standards define a statement-caching interface.

Statement caching can do the following:

- Prevent the overhead of repeated cursor creation
- Prevent repeated statement parsing and creation
- Reuse data structures in the client

This section covers the following topics:

- Basics of Statement Caching
- Implicit Statement Caching
- Explicit Statement Caching

> **Note**
>
> Oracle strongly recommends you use the implicit Statement cache. Oracle JDBC drivers are designed on the assumption that the implicit Statement cache is enabled. So, not using the Statement cache will have a negative impact on performance.

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22.1.1 Basics of Statement Caching

Applications use the Statement cache to cache statements associated with a particular physical connection. The cache is associated with an `OracleConnection` object. `OracleConnection` includes methods to enable Statement caching. When you enable Statement caching, a statement object is cached when you call the `close` method.

Because each physical connection has its own cache, multiple caches can exist if you enable Statement caching for multiple physical connections. When you enable Statement caching on a connection cache, the logical connections benefit from the Statement caching that is enabled on the underlying physical connection. If you try to enable Statement caching on a logical connection held by a connection cache, then this will throw an exception.

There are two types of Statement caching: implicit and explicit. Each type of Statement cache can be enabled or disabled independent of the other. You can have either, neither, or both in effect. Both types of Statement caching share a single cache per connection.

22.1.2 Implicit Statement Caching

When you enable implicit Statement caching, JDBC automatically caches the prepared or callable statement when you call the `close` method of this statement object. The prepared and callable statements are cached and retrieved using standard connection object and statement object methods.

Plain statements are not implicitly cached, because implicit Statement caching uses a SQL string as a key and plain statements are created without a SQL string. Therefore, implicit Statement caching applies only to the `OraclePreparedStatement` and `OracleCallableStatement` objects, which are created with a SQL string. You *cannot* use implicit Statement caching with `OracleStatement`. When you create an `OraclePreparedStatement` or `OracleCallableStatement`, the JDBC driver automatically searches the cache for a matching statement. The match criteria are the following:

- The SQL string in the statement must be identical to one in the cache.
- The statement type must be the same, that is, prepared or callable.
- The scrollable type of result sets produced by the statement must be the same, that is, forward-only or scrollable.

If a match is found during the cache search, then the cached statement is returned. If a match is not found, then a new statement is created and returned. In either case, the statement, along with its cursor and state are cached when you call the `close` method of the statement object.

When a cached `OraclePreparedStatement` or `OracleCallableStatement` object is retrieved, the state and data information are automatically reinitialized and reset to default values, while metadata is saved. Statements are removed from the cache to conform to the maximum size using a Least Recently Used (LRU) algorithm.

> **Note**
>
> The JDBC driver does not clear metadata. However, although metadata is saved for performance reasons, it has no semantic impact. A statement that comes from the implicit cache appears as if it were newly created.

You can prevent a particular statement from being implicitly cached.

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Related Topics

- About Using Implicit Statement Caching

22.1.3 Explicit Statement Caching

Explicit Statement caching enables you to cache and retrieve selected prepared and callable statements. Explicit Statement caching relies on a key, an arbitrary Java `String` that you provide.

> **Note**
>
> Plain statements cannot be cached.

Because explicit Statement caching retains statement data and state as well as metadata, it has a performance edge over implicit Statement caching, which retains only metadata. However, you must be cautious when using this type of caching, because explicit Statement caching saves all three types of information for reuse and you may not be aware of what data and state are retained from prior use of the statements.

Implicit and explicit Statement caching can be differentiated on the following points:

- Retrieving statements

  In the case of implicit Statement caching, you take no special action to retrieve statements from a cache. Instead, whenever you call `prepareStatement` or `prepareCall`, JDBC automatically checks the cache for a matching statement and returns it if found. However, in the case of explicit Statement caching, you use specialized Oracle `WithKey` methods to cache and retrieve statement objects.

- Providing key

  Implicit Statement caching uses the SQL string of a prepared or callable statement as the key, requiring no action on your part. In contrast, explicit Statement caching requires you to provide a Java `String`, which it uses as the key.

- Returning statements

  During implicit Statement caching, if the JDBC driver cannot find a statement in cache, then it will automatically create one. However, during explicit Statement caching, if the JDBC driver cannot find a matching statement in cache, then it will return a `null` value.

Table 22-1 compares the different methods employed in implicit and explicit Statement caching.

Table 22-1 Comparing Methods Used in Statement Caching

Type of Caching	Allocate	Insert Into Cache	Retrieve From Cache
Implicit	`prepareStatement prepareCall`	`close`	`prepareStatement prepareCall`
Explicit	`createStatement prepareStatement prepareCall`	`closeWithKey`	`getStatementWithKey getCallWithKey`

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22.2 About Using Statement Caching

This section discusses the following topics:

- About Enabling and Disabling Statement Caching
- About Closing a Cached Statement
- About Using Implicit Statement Caching
- About Using Explicit Statement Caching

22.2.1 About Enabling and Disabling Statement Caching

When using the `OracleConnection` API, implicit and explicit Statement caching can be enabled or disabled independent of one other. You can have either, neither, or both of them in effect.

Enabling Implicit Statement Caching

There are two ways to enable implicit Statement caching. The first method enables Statement caching on a nonpooled physical connection, where you need to explicitly specify the Statement size for every connection, using the `setStatementCacheSize` method. The second method enables Statement caching on a pooled logical connection. Each connection in the pool has its own Statement cache with the same maximum size that can be specified by setting the `MaxStatementsLimit` property.

Method 1

Perform the following steps:

- Call the `OracleDataSource.setImplicitCachingEnabled(true)` method on the connection to set the `OracleDataSource` property `implicitCachingEnabled` to `true`. For example:

```
OracleDataSource ods =  new OracleDataSource();
...
ods.setImplicitCachingEnabled(true);
...
```

- Call the `OracleConnection.setStatementCacheSize` method on the physical connection. The argument you supply is the maximum number of statements in the cache. For example, the following code specifies a cache size of ten statements:

```
((OracleConnection)conn).setStatementCacheSize(10);
```

Method 2

Perform the following steps:

- Set the `OracleDataSource` properties `implicitCachingEnabled` and `connectionCachingEnabled` to `true`. For example:

```
OracleDataSource ods =  new OracleDataSource();
...
ods.setConnectionCachingEnabled( true );
ods.setImplicitCachingEnabled( true );
...
```

- Set the `MaxStatementsLimit` property to a positive integer on the connection cache, when using the connection cache. For example:

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```
Properties cacheProps = new Properties();
...
cacheProps.put( "MaxStatementsLimit", "50" );
```

To determine whether implicit caching is enabled, call `getImplicitCachingEnabled`, which returns `true` if implicit caching is enabled, `false` otherwise.

> **Note**
>
> Enabling Statement caching enables both implicit and explicit Statement caching.

Disabling Implicit Statement Caching

Disable implicit Statement caching by calling `setImplicitCachingEnabled(false)` on the connection or by setting the `ImplicitCachingEnabled` property to `false`.

Enabling Explicit Statement Caching

To enable explicit Statement caching you must first set the Statement cache size. For setting the cache size, call `OracleConnection.setStatementCacheSize` method on the physical connection. The argument you supply is the maximum number of statements in the cache. An argument of `0` specifies no caching. To check the cache size, use the `getStatementCacheSize` method in the following way:

```
System.out.println("Stmt Cache size is " +
   ((OracleConnection)conn).getStatementCacheSize());
```

The following code specifies a cache size of ten statements:

```
((OracleConnection)conn).setStatementCacheSize(10);
```

Enable explicit Statement caching by calling `setExplicitCachingEnabled(true)` on the connection.

To determine whether explicit caching is enabled, call `getExplicitCachingEnabled`, which returns `true` if explicit caching is enabled, `false` otherwise.

> **Note**
>
> - You enable implicit and explicit caching for a particular physical connection independently. Therefore, it is possible to do Statement caching both implicitly and explicitly during the same session.
> - Implicit and explicit Statement caching share the *same* cache. Remember this when you set the statement cache size.

Disabling Explicit Statement Caching

Disable explicit Statement caching by calling `setExplicitCachingEnabled(false)`. Disabling caching or closing the cache purges the cache. The following example disables explicit Statement caching:

```
((OracleConnection)conn).setExplicitCachingEnabled(false);
```


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22.2.2 About Closing a Cached Statement

Perform the following to close a Statement and assure that it is not returned to the cache:

In J2SE 5.0

- Disable caching for that statement

  ```
  stmt.setDisableStmtCaching(true);
  ```

- Call the `close` method of the statement object

  ```
  stmt.close();
  ```

In JSE 6.0

```
stmt.setPoolable(false);
stmt.close();
```

Physically Closing a Cached Statement

With implicit Statement caching enabled, you cannot physically close statements manually. The `close` method of a statement object caches the statement instead of closing it. The statement is physically closed automatically under one of following three conditions:

- When the associated connection is closed
- When the cache reaches its size limit and the least recently used statement object is preempted from cache by the LRU algorithm
- If you call the `close` method on a statement for which Statement caching is disabled

22.2.3 About Using Implicit Statement Caching

Once you enable implicit Statement caching, by default, all prepared and callable statements are automatically cached. Implicit Statement caching includes the following steps:

1. Enable implicit Statement caching.
2. Allocate a statement using one of the standard methods.
3. Disable implicit Statement caching for any particular statement you do not want to cache. This is an optional step.
4. Cache the statement using the `close` method.
5. Retrieve the implicitly cached statement by calling the appropriate standard prepare method.

Allocating a Statement for Implicit Caching

To allocate a statement for implicit Statement caching, use either the `prepareStatement` or `prepareCall` method as you would typically.

The following code allocates a new statement object called `pstmt`:

```
PreparedStatement pstmt = conn.prepareStatement
   ("UPDATE emp SET ename = ? WHERE rowid = ?");
```


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Disabling Implicit Statement Caching for a Particular Statement

With implicit Statement caching enabled for a connection, by default, all callable and prepared statements of that connection are automatically cached. To prevent a particular callable or prepared statement from being implicitly cached, use the `setDisableStmtCaching` method of the statement object. You can manage cache space by calling the `setDisableStmtCaching` method on any infrequently used statement.

The following code disables implicit Statement caching for `pstmt`:

```
PreparedStatement pstmt = conn.prepareStatement("SELECT 1 from DUAL");
((OraclePreparedStatement)pstmt).setDisableStmtCaching(true);
pstmt.close ();
```

> **Note**
>
> If you are using JSE 6, then you can disable Statement caching by using the standard JDBC 4.0 method `setPoolable`:
>
> ```
> PreparedStatement.setPoolable(false);
> ```
>
> Use the following to check whether the `Statement` object is poolable:
>
> ```
> Statement.isPoolable();
> ```

Implicitly Caching a Statement

To cache an allocated statement, call the `close` method of the statement object. When you call the `close` method on an `OraclePreparedStatement` or `OracleCallableStatement` object, the JDBC driver automatically puts this statement in cache, unless you have disabled caching for this statement.

The following code caches the `pstmt` statement:

```
pstmt.close ();
```

Retrieving an Implicitly Cached Statement

To retrieve an implicitly cached statement, call either the `prepareStatement` or `prepareCall` method, depending on the statement type.

The following code retrieves `pstmt` from cache using the `prepareStatement` method:

```
pstmt = conn.prepareStatement ("UPDATE emp SET ename = ? WHERE rowid = ?");
```

22.2.3.1 Methods Used in Statement Allocation and Implicit Statement Caching

Table 22-2 describes the methods used to allocate statements and retrieve implicitly cached statements.

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Table 22-2 Methods Used in Statement Allocation and Implicit Statement Caching

Method	Functionality for Implicit Statement Caching
`prepareStatement`	Performs a cache search that either finds and returns the desired cached `OraclePreparedStatement` object or allocates a new `OraclePreparedStatement` object if a match is not found
`prepareCall`	Performs a cache search that either finds and returns the desired cached `OracleCallableStatement` object or allocates a new `OracleCallableStatement` object if a match is not found

Example 22-1 provides a sample code that shows how to enable implicit statement caching.

Example 22-1 Using Implicit Statement Cache

```
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.Properties;
import javax.sql.DataSource;
import oracle.jdbc.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;
public class TestJdbc
{
  /**
   * Get a Connection, prepare a statement, execute a query, fetch the results, close
the connection.
   * @param ods the DataSource used to get the connection.
   */
  private static void doSQL( DataSource ods ) throws SQLException
  {
    final String SQL = "select username from all_users";
    OracleConnection  conn = null;
    PreparedStatement ps = null;
    ResultSet rs = null;
    try
    {
      conn = (OracleConnection) ods.getConnection();
      System.out.println( "Connection:" + conn );
      System.out.println( "Connection getImplicitCachingEnabled:" +
conn.getImplicitCachingEnabled() );
      System.out.println( "Connection getStatementCacheSize:" +
conn.getStatementCacheSize() );
      ps = conn.prepareStatement( SQL );
      System.out.println( "PreparedStatement:" + ps );
      rs = ps.executeQuery();
      while ( rs.next() )
      {
        String owner = rs.getString( 1 );
        System.out.println( owner );
      }
    }
    finally
    {
      if ( rs != null )
      {
        rs.close();
      }
      if ( ps != null )
      {
```


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```
        ps.close();
      conn.close();
    }
  }
  }
  public static void main( String[] args )
  {
    try
    {
      OracleDataSource ods =  new OracleDataSource();
      ods.setDriverType( "thin" );
      ods.setServerName( "localhost" );
      ods.setPortNumber( 5221 );
      ods.setServiceName( "orcl" );
      ods.setUser( "HR" );
      ods.setPassword( "hr" );
      ods.setConnectionCachingEnabled( true );
      ods.setImplicitCachingEnabled( true );
      Properties cacheProps = new Properties();
      cacheProps.put( "InitialLimit", "1" );
      cacheProps.put( "MinLimit", "1" );
      cacheProps.put( "MaxLimit", "5" );
      cacheProps.put( "MaxStatementsLimit", "50" );
      ods.setConnectionCacheProperties( cacheProps );
      System.out.println( "DataSource getImplicitCachingEnabled: " +
ods.getImplicitCachingEnabled() );
      for ( int i = 0; i < 5; i++ )
      {
        doSQL( ods );
      }
    }
    catch ( Exception ex )
    {
      ex.printStackTrace();
    }
  }
}
```

22.2.4 About Using Explicit Statement Caching

A prepared or callable statement can be explicitly cached when you enable explicit Statement caching. Explicit Statement caching includes the following steps:

1. Enable explicit Statement caching.
2. Allocate a statement using one of the standard methods.
3. Explicitly cache the statement by closing it with a key, using the `closeWithKey` method.
4. Retrieve the explicitly cached statement by calling the appropriate Oracle WithKey method, specifying the appropriate key.
5. Re-cache an open, explicitly cached statement by closing it again with the `closeWithKey` method. Each time a cached statement is closed, it is re-cached with its key.

Allocating a Statement for Explicit Caching

To allocate a statement for explicit Statement caching, use either the `createStatement`, `prepareStatement`, or `prepareCall` method as you would typically.

The following code allocates a new statement object called `pstmt`:

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```
PreparedStatement pstmt =
   conn.prepareStatement ("UPDATE emp SET ename = ? WHERE rowid = ?");
```

Explicitly Caching a Statement

To explicitly cache an allocated statement, call the `closeWithKey` method of the statement object, specifying a key. The key is an arbitrary Java `String` that you provide. The `closeWithKey` method caches a statement as is. This means the data, state, and metadata are retained and not cleared.

The following code caches the `pstmt` statement with the key `"mykey"`:

```
((OraclePreparedStatement)pstmt).closeWithKey ("mykey");
```

Retrieving an Explicitly Cached Statement

To recall an explicitly cached statement, call either the `getStatementWithKey` or `getCallWithKey` methods depending on the statement type.

If you retrieve a statement with a specified key, then the JDBC driver searches the cache for the statement, based on the specified key. If a match is found, then the matching statement is returned along with its state, data, and metadata. This information is as it was when the statement was last closed. If a match is not found, then the JDBC driver returns `null`.

The following code recalls `pstmt` from cache using the `"mykey"` key with the `getStatementWithKey` method. Recall that the `pstmt` statement object was cached with the `"mykey"` key.

```
pstmt = ((OracleConnection)conn).getStatementWithKey ("mykey");
```

If you call the `creationState` method on the `pstmt` statement object, then the method returns `EXPLICIT`.

> **Note**
>
> When you retrieve an explicitly cached statement, ensure that you use the method that is appropriate for your statement type when specifying the key. For example, if you used the `prepareStatement` method to allocate a statement, then use the `getStatementWithKey` method to retrieve that statement from cache. The JDBC driver does *not* verify the type of statement it is returning.

22.2.4.1 Methods Used to Retrieve Explicitly Cached Statements

Table 22-3 describes the methods used to retrieve explicitly cached statements.

Table 22-3 Methods Used to Retrieve Explicitly Cached Statements

Method	Functionality for Explicit Statement Caching
`getStatementWithKey`	Specifies the key needed to retrieve a prepared statement from cache
`getCallWithKey`	Specifies the key needed to retrieve a callable statement from cache

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22.3 About Reusing Statements Objects

The JDBC 3.0 specification introduces the feature of statement pooling that enables an application to reuse a `PreparedStatement` object in the same way as it uses a `Connection` object. The `PreparedStatement` objects can be reused by multiple logical connections in a transparent manner.

This section covers the following topics:

- About Using a Pooled Statement
- About Closing a Pooled Statement

> **Note**
>
> The Oracle JDBC Drivers use implicit statement caching to support statement pooling.

22.3.1 About Using a Pooled Statement

An application can find out whether a data source supports statement pooling by calling the `isPoolable` method from the `Statement` interface. If the return value is `true`, then the application knows that the `PreparedStatement` object is being pooled. The application can also request a statement to be pooled or not pooled by using the `setPoolable` method from the `Statement` interface.

Reusing of pooled statement should be completely transparent to the application, that is, the application code should remain the same whether a `PreparedStatement` object participates in statement pooling or not. If an application closes a `PreparedStatement` object, it must still call `Connection.prepareStatement` method in order to reuse it.

> **Note**
>
> An application has no direct control over how statements are pooled. A pool of statements is associated with a `PooledConnection` object, whose behavior is determined by the properties of the `ConnectionPoolDataSource` object that produced it.

22.3.2 About Closing a Pooled Statement

An application closes a pooled statement exactly the same way it closes a nonpooled statement. Once a statement is closed, whether is it pooled or nonpooled, it is no longer available for use by the application and an attempt to reuse it causes an exception to be thrown. The only difference visible is that an application cannot directly close a physical statement that is being pooled. This is done by the pool manager. The method `PooledConnection.closeAll` closes all of the statements open on a given physical connection, which releases the resources associated with those statements.

The following methods can close a pooled statement:

- `close`

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This `java.sql.Statement` interface method is called by an application. If the statement is being pooled, then it closes the logical statement used by the application but does not close the physical statement being pooled.

- `close`

  This `java.sql.Connection` interface method is called by an application. This method acts differently depending upon whether the connection using the statement is being pooled or not:

  – Nonpooled connection

    This method closes the physical connection and all statements created by that connection. This is necessary because the garbage collection mechanism is unable to detect when externally managed resources can be released.

  – Pooled connection

    This method closes the logical connection and the logical statements it returned, but leaves open the underlying `PooledConnection` object and any associated pooled statements

- `PooledConnection.closeAll`

  This method is called by the connection pool manager to close all of the physical statements being pooled by the `PooledConnection` object

22.4 About Result Set Caching

Your applications sometime send repetitive queries to the database. To improve the response time of repetitive queries, results of queries, query fragments, and PL/SQL functions can be cached in memory. A result cache stores the results of queries shared across all sessions. When these queries are executed repeatedly, the results are retrieved directly from the cache memory.

> **Note**
>
> If a result set is very large, then it may not be cached due to size restrictions.

You must annotate a query or query fragment with a result cache hint to indicate that results are to be stored in the query result cache.

The query result set can be cached in the following ways:

- Server-Side Result Set Cache
- Client-Side Result Set Cache

> **Note**
>
> - The server-side and client result set caches are most useful for read-only or read-mostly data. They may reduce performance for queries with highly dynamic results.
> - Both server-side and client result set caches use memory. So, caching very large result sets can cause performance problems.

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22.4.1 Server-Side Result Set Cache

Support for server-side Result Set caching has been introduced for both JDBC Thin and JDBC Oracle Call Interface (OCI) drivers since Oracle Database 11*g* Release 1. The server-side result cache is used to cache the results of the current queries, query fragments, and PL/SQL functions in memory and then to use the cached results in future executions of the query, query fragment, or PL/SQL function. The cached results reside in the result cache memory portion of the SGA. A cached result is automatically invalidated whenever a database object used in its creation is successfully modified. The server-side caching can be of the following two types:

- SQL Query Result Cache
- PL/SQL Function Result Cache

See Also

- *Oracle Database Performance Tuning Guide* for more information about SQL Query Result Cache
- *Oracle Database PL/SQL Language Reference* for more information about PL/SQL Function Result Cache

22.4.2 Client-Side Result Set Cache

Client-side result set cache feature enables client-side caching of SQL query result sets in client memory. In this way, the applications can use client memory to take advantage of the client-side result set cache to improve response times of repetitive queries.

This section covers the following topics:

- Enabling the Client-Side Result Set Cache
- Benefits of Client-Side Result Set Cache
- Usage Guidelines in JDBC

22.4.2.1 Enabling the Client-Side Result Set Cache

Oracle Database Release 23ai supports client-side result set cache in the JDBC thin driver. You can use the new `oracle.jdbc.enableQueryResultCache` connection property for enabling this feature. The default value of this property is `true`, which means that this feature is enabled by default. You can disable this feature by setting the property to `false`.

See Also

Oracle Call Interface Programmer's Guide

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For using this feature, you must set the following database initialization parameters in the following way:

```
CLIENT_RESULT_CACHE_SIZE=100M
CLIENT_RESULT_CACHE_LAG=1000
```

This value of the `CLIENT_RESULT_CACHE_SIZE` parameter controls how much memory the thin driver can use for its cache.

A read-only or read-mostly table can then be annoted and its data can be cached on the driver. For example, `RESULT_CACHE(MODE FORCE)`.

You can also use a SQL hint `/*+RESULT_CACHE */` for identifying queries that are eligible for caching.

> **See Also**
>
> *Oracle Database JDBC Java API Reference*

22.4.2.2 Benefits of Client-Side Result Set Cache

The benefits of the client-side result set cache are the following:

- The client-side result set cache is completely transparent to the applications and its cache of result set data is kept consistent with any session or database changes that affect its result set.
- Table annotation makes client-side result set work transparently to the JDBC applications. Otherwise, you must use a hint to enable it. The cache hit avoids the execution of the query and roundtrip to the server to get the result sets. This can result in huge performance savings for server resources, for example, server CPU and server I/O.

  > **See Also**
  >
  > Table Annotations and SQL Hints

- The result cache on the client is per-process, so multiple client sessions can simultaneously use matching cached result sets.
- The result cache on the client minimizes the need for each application to have its own custom result set cache.
- The result cache on the client uses the client memory that is cheaper than server memory.

22.4.2.3 Usage Guidelines in JDBC

You can enable result set caching in the following three ways:

- The RESULT_CACHE_MODE Parameter
- The RESULT_CACHE_INTEGRITY Parameter
- Table Annotations
- SQL Hints

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> **Note**
>
> - You must use JDBC statement caching or cache statements at the application level when using the client-side result set cache.
> - The SQL hints take precedence over the session parameter `RESULT_CACHE_MODE` and table annotations. The table annotation `FORCE` takes precedence over session parameter.
> - If you set the value of the `RESULT_CACHE_INTEGRITY` parameter to `TRUSTED`, then the Database honors the setting of the `RESULT_CACHE_MODE` parameter and the specified hints, and considers queries using possibly non-deterministic constructs as candidates for result caching.

Related Topics

- Statement and Result Set Caching

22.4.2.3.1 The RESULT_CACHE_MODE Parameter

You can use the `RESULT_CACHE_MODE` parameter to decide the result cache mode across tables in your queries.

Use this clause with the `ALTER SESSION` and `ALTER SYSTEM` statements, or inside the server parameter file (`init.ora`) to determine result caching. You can set the `RESULT_CACHE_MODE` parameter to control whether the SQL query result cache is used for all queries, or only for the queries that are annotated with the result cache hint using SQL hints or table annotations.

> **See Also**
>
> RESULT_CACHE_MODE

22.4.2.3.2 The RESULT_CACHE_INTEGRITY Parameter

You can use the `RESULT_CACHE_INTEGRITY` parameter to specify whether the result cache must consider queries using non-deterministic constructs, such as PL/SQL functions, because those are not declared as deterministic. You can use this parameter to enforce explicit declaration of objects as deterministic, prior to their consideration in the result cache.

> **See Also**
>
> - Setting Result Cache Integrity
> - RESULT_CACHE_INTEGRITY

22.4.2.3.3 Table Annotations

You can use table annotations to enable result caching without making changes to the code. The `ALTER TABLE` and `CREATE TABLE` statements enable you to annotate tables with result cache mode. The syntax is:

```
CREATE|ALTER TABLE [<schema>.]<table> ... [RESULT_CACHE (MODE {FORCE|DEFAULT})]
```


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Following example shows how to use table annotations with `CREATE TABLE` statements:

```
CREATE TABLE foo (a NUMBER, b VARCHAR2(20)) RESULT_CACHE (MODE FORCE);
```

Following example shows how to use table annotations with `ALTER TABLE` statements:

```
ALTER TABLE foo RESULT_CACHE (MODE DEFAULT);
```

22.4.2.3.4 SQL Hints

You can use SQL hints to specify the queries to be cached by annotating the queries with a `/*+ result_cache */` or /*+ no_result_cache */ hint.

For example, look at the following code snippet:

```
String  query  = "select /*+ result_cache */ * from employees where employee_id < : 1";
   ((oracle.jdbc.OracleConnection)conn).setImplicitCachingEnabled(true);
   ((oracle.jdbc.OracleConnection)conn).setStatementCacheSize(10);
   PreparedStatement  pstmt;
   ResultSet rs;

    for (int j = 0 ; j < 10 ; j++ )
    {
       pstmt  = conn.prepareStatement (query);
       pstmt.setInt(1,7500);
       rs  = pstmt.executeQuery();
         while (rs.next( ) )
        {     // see the values  }
          rs.close;
          pstmt.close( ) ;
        }
    }
```

In the preceding example, the client result cache hint `/*+ result_cache */` is annotated to the actual query, that is, `select * from employees where employee_id < : 1`. So, the first execution of the query goes to the database and the result set is cached for the remaining nine executions of the query. This improves the performance of your application significantly. This is primarily useful for read-only data.

Following are some more examples of SQL hints. All the following examples assume that the `departments` table is annotated for result caching by using the following command:

```
ALTER TABLE departments result_cache (MODE FORCE);
```

Examples

- SELECT * FROM employees

  The result set will not be cached.
- SELECT * FROM departments

  The result set will be cached.
- SELECT /*+ result_cache */ employee_id FROM employees

  The result set will be cached.
- SELECT /*+ no_result_cache */ department_id FROM departments

  The result set will not be cached.
- SELECT /*+ result_cache */ * FROM departments

  The result set will be cached though query hint is not necessary.

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- SELECT e.first_name FROM employees e, departments d WHERE e.department_id = d.department_id

  The result set will not be cached because neither is a query hint available nor are all the tables annotated as `FORCE`.

> **Note**
>
> For information about usage guidelines, Client cache consistency, Deployment Time settings, Client cache Statistics, Validation of client result cache, and OCI Client Result Cache and Server Result Cache, refer to the *Oracle Call Interface Programmer's Guide*.

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23
Performance Extensions

This chapter describes the Oracle performance extensions to the Java Database Connectivity (JDBC) standard.

This chapter covers the following topics:

- Update Batching
- Additional Oracle Performance Extensions

> **Note**
>
> Oracle update batching was deprecated in Oracle Database 12*c* Release 1 (12.1). Starting with Oracle Database 12*c* Release 2 (12.2), Oracle update batching is a no operation code (no-op). This means that if you implement Oracle update batching in your application, using the current release of Oracle JDBC driver, then the specified batch size is not set, and it results in a batch size of 1. With this batch setting, your application processes one row at a time. Oracle strongly recommends that you use the standard JDBC batching.

23.1 Update Batching

This section covers the following topics:

- Overview of Update Batching
- Standard Update Batching
- Premature Batch Flush

23.1.1 Overview of Update Batching

Update batching is especially useful with prepared statements, when you are repeating the same statement with different bind variables.

You can reduce the number of round-trips to the database and improve the application performance, by grouping multiple `UPDATE`, `DELETE`, or `INSERT` statements into a single batch, and then having the whole batch sent to the database and processed in one trip. This is referred to as 'update batching'.

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> **Note**
>
> - The JDBC 2.0 specification refers to 'update batching' as 'batch updates'.
> - To adhere to the JDBC 2.0 standard, Oracle implementation of standard update batching supports callable statements without `OUT` parameters, generic statements, and prepared statements. You can migrate standard update batching into an Oracle JDBC application without difficulty. However, the Oracle implementation of standard update batching does not implement true batching for generic statements and callable statements and you will see performance improvement for only `PreparedStatement` objects.

23.1.2 Standard Update Batching

JDBC standard update batching depends on explicitly adding statements to the batch using an `addBatch` method and explicitly processing the batch using an `executeBatch` method.

> **Note**
>
> Disable auto-commit mode when you use update batching. In case an error occurs while you are processing a batch, this provides you the option of committing or rolling back the operations that ran successfully prior to the error.

23.1.2.1 About Adding Operations to the Batch

When any statement object is first created, its statement batch is empty. Use the standard `addBatch` method to add an operation to the statement batch. This method is specified in the standard `java.sql.Statement`, `PreparedStatement`, and `CallableStatement` interfaces, which are implemented by the `oracle.jdbc.OracleStatement`, `OraclePreparedStatement`, and `OracleCallableStatement` interfaces, respectively.

> **Note**
>
> Starting from Oracle Databse Release 23ai, when you use the `addBatch` method, the JDBC driver starts a pipeline with the Database, which results in improved response time and throughput. See Support for Pipelined Database Operations.

For a `Statement` object, the `addBatch` method takes a Java `String` with a SQL operation as input. For example:

```
...
Statement stmt = conn.createStatement();

stmt.addBatch("INSERT INTO emp VALUES(1000, 'Joe Jones')");
stmt.addBatch("INSERT INTO dept VALUES(260, 'Sales')");
stmt.addBatch("INSERT INTO emp_dept VALUES(1000, 260)");
...
```

At this point, three operations are in the batch.

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For prepared statements, update batching is used to batch multiple runs of the same statement with different sets of bind parameters. For a `PreparedStatement` or `OraclePreparedStatement` object, the `addBatch` method takes no input. It simply adds the operation to the batch using the bind parameters last set by the appropriate `setXXX` methods. This is also true for `CallableStatement` or `OracleCallableStatement` objects, but remember that in the Oracle implementation of standard update batching, you will probably see no performance improvement in batching callable statements.

For example:

```
...
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();
...
```

At this point, two operations are in the batch.

Because a batch is associated with a single prepared statement object, you can batch only repeated runs of a single prepared statement, as in this example.

23.1.2.2 About Processing the Batch

To process the current batch of operations, use the `executeBatch` method of the statement object. This method is specified in the standard `Statement` interface, which is extended by the standard `PreparedStatement` and `CallableStatement` interfaces.

Following is an example that repeats the prepared statement `addBatch` calls shown previously and then processes the batch:

```
...
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();

int[] updateCounts = pstmt.executeBatch();
...
```

If you add too many operations to a batch by calling the `addBatch` method several times and create a very large batch (for example, with more than or equal to 100,000 rows), then while calling the `executeBatch` method on the whole batch, you may face severe performance problems in terms of memory. To avoid this issue, the earlier JDBC drivers used to transparently break up the large batches into smaller internal batches to make a round-trip to the server for each internal batch. This made your application slightly slower because of each round-trip overhead, but optimized memory significantly. However, if each bound row was very large in size (for example, more than about 1MB each or so), then this process could impact

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the overall performance negatively because, in such a case, the performance gained in terms of memory was less than the performance lost in terms of time.

Starting from Oracle Database 23ai Release, the batches are no longer split, unless you configure the `CONNECTION_PROPERTY_MAX_BATCH_MEMORY` property. This property configures the maximum amount of memory allocated by the `executeBatch` and `executeLargeBatch` methods, when you convert Java bind values to SQL data types. The value of this property is measured in bytes. The default value is 0, which means that there is no limit on the maximum amount of memory allocated.

See Also

Oracle JDBC Java API Reference

23.1.2.3 Row Count per Iteration for Array DMLs

Starting from Oracle Database 12*c* Release 1 (12.1), the `executeBatch` method has been improved so that it returns an int array of size that is the same as the number of records in the batch and each item in the return array is the number of database table rows affected by the corresponding record of the batch. For example, if the batch size is 5, then the `executeBatch` method returns an array of size 5. In case of an error in between execution of the batch, the `executeBatch` method cannot return a value, instead it throws a `BatchUpdateException`. In this case, the exception itself carries an int array of size `n` as its data, where `n` is the number of successful record executions. For example, if the batch is of size 5 and the error occurs at the 4th record, then the `BatchUpdateException` has an array of size 3 (3 records executed successfully) and each item in the array represents how many rows were affected by each of them.

23.1.2.4 About Committing the Changes in the Oracle Implementation of Standard Batching

After you process the batch, you must still commit the changes, presuming auto-commit is disabled as recommended.

Calling `commit`, commits nonbatched operations and batched operations for statement batches that have been processed, but for the Oracle implementation of standard batching, has no effect on pending statement batches that have *not* been processed.

23.1.2.5 About Clearing the Batch

To clear the current batch of operations instead of processing it, use the `clearBatch` method of the statement object. This method is specified in the standard `Statement` interface, which is extended by the standard `PreparedStatement` and `CallableStatement` interfaces.

Keep the following things in mind:

- When a batch is processed, operations are performed in the order in which they were batched.
- After calling `addBatch`, you must call either `executeBatch` or `clearBatch` before a call to `executeUpdate`, otherwise there will be a SQL exception.
- A `clearBatch` or `executeBatch` call resets the statement batch to empty.

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- The statement batch is not reset to empty if the connection receives a `ROLLBACK` request. You must explicitly call `clearBatch` to reset it.
- Invoking `clearBatch` method after a rollback works for all releases.
- An `executeBatch` call closes the current result set of the statement object, if one exists.
- Nothing is returned by the `clearBatch` method.

Following is an example that repeats the prepared statement `addBatch` calls shown previously but then clears the batch under certain circumstances:

```
...
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();

if (...condition...)
{
   int[] updateCounts = pstmt.executeBatch();
   ...
}
else
{
   pstmt.clearBatch();
   ...
}
```

23.1.2.6 Update Counts in the Oracle Implementation of Standard Batching

If a statement batch is processed successfully, then the integer array, or update counts array, returned by the statement `executeBatch` call will always have one element for each operation in the batch. In the Oracle implementation of standard update batching, the values of the array elements are as follows:

- For a prepared statement batch, the array contains the actual update counts indicating the number of rows affected by each operation.
- For a generic statement batch, the array contains the actual update counts indicating the number of rows affected by each operation. The actual update counts can be provided only in the case of generic statements in the Oracle implementation of standard batching.
- For a callable statement batch, the array contains the actual update counts indicating the number of rows affected by each operation.

In your code, upon successful processing of a batch, you should be prepared to handle either `-2`, `1`, or true update counts in the array elements. For a successful batch processing, the array contains either all `-2`, `1`, or all positive integers.

Example 23-1 illustrates the use of standard update batching.

Example 23-1 Standard Update Batching

This example combines the sample fragments in the previous sections, accomplishing the following steps:

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1. Disabling auto-commit mode, which you should always perform when using update batching
2. Creating a prepared statement object
3. Adding operations to the batch associated with the prepared statement object
4. Processing the batch
5. Committing the operations from the batch

```
conn.setAutoCommit(false);

PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");
pstmt.addBatch();

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();

int[] updateCounts = pstmt.executeBatch();

conn.commit();

pstmt.close();
...
```

You can process the update counts array to determine if the batch processed successfully.

23.1.2.7 Error Handling in the Oracle Implementation of Standard Batching

If any one of the batched operations fails to complete successfully or attempts to return a result set during an `executeBatch` call, then the processing stops and a `java.sql.BatchUpdateException` is generated.

After a batch exception, the update counts array can be retrieved using the `getUpdateCounts` method of the `BatchUpdateException` object. This returns an `int` array of update counts, just as the `executeBatch` method does. In the Oracle implementation of standard update batching, contents of the update counts array are as follows, after a batch is processed:

- For a prepared statement batch, in case of an error in between execution of the batch, the `executeBatch` method cannot return a value, instead it throws a `BatchUpdateException`. In this case, the exception itself carries an int array of size `n` as its data, where `n` is the number of successful record executions. For example, if the batch is of size 5 and the error occurs at the 4th record, then the `BatchUpdateException` has an array of size 3 (3 records executed successfully) and each item in the array represents how many rows were affected by each of them.
- For a generic statement batch or callable statement batch, the update counts array is only a partial array containing the actual update counts up to the point of the error. The actual update counts can be provided because Oracle JDBC cannot use true batching for generic and callable statements in the Oracle implementation of standard update batching.

  For example, if there were 20 operations in the batch, the first 13 succeeded, and the 14th generated an exception, then the update counts array will have 13 elements, containing actual update counts of the successful operations.

  You can either commit or roll back the successful operations in this situation, as you prefer.

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In your code, upon failed processing of a batch, you should be prepared to handle either `-3` or true update counts in the array elements when an exception occurs. For a failed batch processing, you will have either a full array of `-3` or a partial array of positive integers.

23.1.2.8 About Intermixing Batched Statements and Nonbatched Statements

You cannot call `executeUpdate` for regular, nonbatched processing of an operation if the statement object has a pending batch of operations.

However, you can intermix batched operations and nonbatched operations in a single statement object if you process nonbatched operations either prior to adding any operations to the statement batch or after processing the batch. Essentially, you can call `executeUpdate` for a statement object only when its update batch is empty. If the batch is non-empty, then an exception will be generated.

For example, it is valid to have a sequence, such as the following:

```
...
PreparedStatement pstmt =
          conn.prepareStatement("INSERT INTO employees VALUES(?, ?)");

pstmt.setInt(1, 2000);
pstmt.setString(2, "Milo Mumford");

int scount = pstmt.executeUpdate();   // OK; no operations in pstmt batch

pstmt.setInt(1, 3000);
pstmt.setString(2, "Sulu Simpson");
pstmt.addBatch();                    // Now start a batch

pstmt.setInt(1, 4000);
pstmt.setString(2, "Stan Leland");
pstmt.addBatch();

int[] bcounts = pstmt.executeBatch();

pstmt.setInt(1, 5000);
pstmt.setString(2, "Amy Feiner");

int scount = pstmt.executeUpdate();   // OK; pstmt batch was executed
...
```

Intermixing nonbatched operations on one statement object and batched operations on another statement object within your code is permissible. Different statement objects are independent of each other with regard to update batching operations. A `COMMIT` request will affect all nonbatched operations and all successful operations in processed batches, but will not affect any pending batches.

23.1.2.9 Limitations in the Oracle Implementation of Standard Batching

This section discusses the limitations and implementation details regarding the Oracle implementation of standard update batching.

In Oracle JDBC applications, update batching is intended for use with prepared statements that are being processed repeatedly with different sets of bind values.

The Oracle implementation of standard update batching does not implement true batching for generic statements and callable statements. Even though Oracle JDBC supports the use of standard batching for `Statement` and `CallableStatement` objects, you are unlikely to see performance improvement.

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23.1.3 Premature Batch Flush

Premature batch flush happens due to a change in cached metadata. Cached metadata can be changed due to various reasons, such as the following:

- The initial bind was null and the following bind is not null.
- A scalar type is initially bound as string and then bound as scalar type or the reverse.

The premature batch flush count is summed to the return value of the next `executeUpdate` or `sendBatch` method.

The old functionality lost all these batch flush values which can be obtained now. To switch back to the old functionality, you can set the `AccumulateBatchResult` property to `false`, as follows:

```
java.util.Properties info = new java.util.Properties();
info.setProperty("user", "HR");
info.setProperty("passwd", "hr");
// other properties
...

// property: batch flush type
info.setProperty("AccumulateBatchResult", "false");

OracleDataSource ods = new OracleDataSource();
ods.setConnectionProperties(info);
ods.setURL("jdbc:oracle:oci:@"");
Connection conn = ods.getConnection();
```

> **Note**
>
> The `AccumulateBatchResult` property is set to `true` by default.

Example 23-2 illustrates premature batch flushing.

Example 23-2 Premature Batch Flushing

```
((OraclePreparedStatement)pstmt).setExecuteBatch (2);

pstmt.setNull(1, OracleTypes.NUMBER);
pstmt.setString(2, "test11");
int count = pstmt.executeUpdate(); // returns 0

/*
* Premature batch flush happens here.
*/
pstmt.setInt(1, 22);
pstmt.setString(2, "test22");
int count = pstmt.executeUpdate(); // returns 0

pstmt.setInt(1, 33);
pstmt.setString(2, "test33");
/*
*  returns 3 with the new batching scheme where as,
*  returns 2 with the old batching scheme.
*/
int count = pstmt.executeUpdate();
```


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23.2 Additional Oracle Performance Extensions

In addition to update batching, Oracle JDBC drivers support the extensions discussed in this chpter, which improve performance by reducing round-trips to the database:

- Prefetching rows

  This reduces round-trips to the database by fetching multiple rows of data each time data is fetched. The extra data is stored in client-side buffers for later access by the client. The number of rows to prefetch can be set as desired.

- Specifying column types

  This avoids an inefficiency in the standard JDBC protocol for performing and returning the results of queries.

- Suppressing database metadata `TABLE_REMARKS` columns

  This avoids an expensive outer join operation.

Oracle provides several extensions to connection properties objects to support these performance extensions. These extensions enable you to set the `remarksReporting` flag and default values for row prefetching and update batching.

This section covers the following topics:

- Oracle Row-Prefetching Limitations
- About Defining Column Types
- About Reporting DatabaseMetaData TABLE_REMARKS

23.2.1 Oracle Row-Prefetching Limitations

There is no maximum prefetch setting. The default value is 10. Larger or smaller values may be appropriate depending on the number of rows and columns expected from the query. You can set the default connection row-prefetch value using a `Properties` object.

When a statement object is created, it receives the default row-prefetch setting from the associated connection. Subsequent changes to the default connection row-prefetch setting will have no effect on the statement row-prefetch setting.

If a column of a result set is of data type `LONG`, `LONG RAW` or `LOB`s returned through the data interface, that is, the streaming types, then JDBC changes the statement row-prefetch setting to 1, even if you never actually read a value of either of these types.

Setting the prefetch size can affect the performance of an application. Increasing the prefetch size will reduce the number of round-trips required to get all the data, but will increase memory usage. This will depend on the number and size of the columns in the query and the number of rows expected to be returned. It will also depend on the memory and CPU loading of the JDBC client machine. The optimum for a standalone client application will be different from a heavily loaded application server. The speed and latency of the network connection should also be considered.

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> **Note**
>
> Starting from Oracle Database 11*g* Release 1, the Thin driver can fetch the first `prefetch_size` number of rows from the server in the very first round-trip. This saves one round-trip in SELECT statements.

If you are migrating an application from earlier releases of Oracle JDBC drivers to 10*g* Release 1 (10.1) or later releases of Oracle JDBC drivers, then you should revisit the optimizations that you had done earlier, because the memory usage and performance characteristics may have changed substantially.

A common situation that you may encounter is, say, you have a query that selects a unique key. The query will return only zero or one row. Setting the prefetch size to 1 will decrease memory and CPU usage and cannot increase round-trips. However, you must be careful to avoid the error of requesting an extra fetch by writing `while(rs.next())` instead of `if(rs.next())`.

If you are using the JDBC Thin driver, then use the `useFetchSizeWithLongColumn` connection property, because it will perform `PARSE`, `EXECUTE`, and `FETCH` in a single round-trip.

Tuning of the prefetch size should be done along with tuning of memory management in your JVM under realistic loads of the actual application.

> **Note**
>
> - Do not mix the JDBC 2.0 fetch size application programming interface (API) and the Oracle row-prefetching API in your application. You can use one or the other, but not both.
> - Be aware that setting the Oracle fetch size value can affect not only queries, but also explicitly refetching rows in a result set through the result set `refreshRow` method, which is relevant for scroll-sensitive/read-only, scroll-sensitive/updatable, and scroll-insensitive/updatable result sets, and the window size of a scroll-sensitive result set, affecting how often automatic refetches are performed. However, the Oracle fetch size value will be overridden by any setting of the fetch size.

23.2.2 About Defining Column Types

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), the `defineColumnType` method is deprecated.

The implementation of `defineColumnType` changed significantly since Oracle Database 10*g*. Previously, `defineColumnType` was used both as a performance optimization and to force data type conversion. In previous releases, all of the drivers benefited from calls to `defineColumnType`. Starting from Oracle Database 10*g*, the JDBC Thin driver no longer needs the information provided. The JDBC Thin driver achieves maximum performance without calls

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to `defineColumnType`. The JDBC Oracle Call Interface (OCI) and server-side internal drivers still get better performance when the application uses `defineColumnType`.

If your code is used with both the JDBC Thin and OCI drivers, you can disable the `defineColumnType` method when using the Thin driver by setting the connection property `disableDefineColumnType` to `true`. Doing this makes `defineColumnType` have no effect. Do not set this connection property to `true` when using the JDBC OCI or server-side internal drivers.

You can also use `defineColumnType` to control how much memory the client-side allocates or to limit the size of variable-length data.

Follow these general steps to define column types for a query:

1. If necessary, cast your statement object to `OracleStatement`, `OraclePreparedStatement`, or `OracleCallableStatement`, as applicable.
2. If necessary, use the `clearDefines` method of your `Statement` object to clear any previous column definitions for this `Statement` object.
3. On each column, call the `defineColumnType` method of your `Statement` object, passing it these parameters:
   - Column index (integer)
   - Type code (integer)

     Use the `static` constants of the `java.sql.Types` class or `oracle.jdbc.OracleTypes` class, such as `Types.INTEGER`, `Types.FLOAT`, `Types.VARCHAR`, `OracleTypes.VARCHAR`, and `OracleTypes.ROWID`. Type codes for standard types are identical in these two classes.
   - Type name (string)

     For structured objects, object references, and arrays, you must also specify the type name. For example, `Employee`, `EmployeeRef`, or `EmployeeArray`.
   - Maximum field size (integer)

     Optionally specify a maximum data length for this column.

     You cannot specify a maximum field size parameter if you are defining the column type for a structured object, object reference, or array. If you try to include this parameter, it will be ignored.
   - Form of use (short)

     Optionally specify a form of use for the column. This can be `OraclePreparedStatement.FORM_CHAR` to use the database character set or `OraclePreparedStatement.FORM_NCHAR` to use the national character set. If this parameter is omitted, the default is `FORM_CHAR`.

   For example, assuming `stmt` is an Oracle statement, use:

   ```
   stmt.defineColumnType(column_index, typeCode);
   ```

   If the column is `VARCHAR` or equivalent and you know the length limit:

   ```
   stmt.defineColumnType(column_index, typeCode, max_size);
   ```

   For an `NVARCHAR` column where the original maximum length is desired and conversion to the database character set is requested:

   ```
   stmt.defineColumnType(column_index, typeCode, 0,
      OraclePreparedStatement.FORM_CHAR );
   ```


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For structured object, object reference, and array columns:

```
stmt.defineColumnType(column_index, typeCode, typeName);
```

Set a maximum field size if you do not want to receive the full default length of the data. Calling the `setMaxFieldSize` method of the standard JDBC `Statement` class sets a restriction on the amount of data returned. Specifically, the size of the data returned will be the minimum of the following:

- The maximum field size set in `defineColumnType`
- The maximum field size set in `setMaxFieldSize`
- The natural maximum size of the data type

After you complete these steps, use the `executeQuery` method of the statement to perform the query.

> **Note**
>
> It is no longer necessary to specify a data type for each column of the expected result set.

The following example illustrates the use of this feature. It assumes you have imported the `oracle.jdbc.*` interfaces.

Example 23-3 Defining Column Types

```
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:oracle:thin:@localhost:5221:orcl");
ods.setUser("HR");
ods.setPassword("hr");
Connection conn = ods.getConnection();

Statement stmt = conn.createStatement();
// Allocate only 2 chars for this column (truncation will happen)
((OracleStatement)stmt).defineColumnType(1, Types.VARCHAR, 2);
ResultSet rset = stmt.executeQuery("select ename from emp");
while(rset.next() )
  System.out.println(rset.getString(1));
stmt.close();
```

As this example shows, you must cast the `Statement` object, `stmt`, to `OracleStatement` in the invocation of the `defineColumnType` method. The `createStatement` method of the connection returns an object of type `java.sql.Statement`, which does not have the `defineColumnType` and `clearDefines` methods. These methods are provided only in the `OracleStatement` implementation.

The define-extensions use JDBC types to specify the desired types. The allowed define types for columns depend on the internal Oracle type of the column.

All columns can be defined to their natural JDBC types. In most cases, they can be defined to the `Types.CHAR` or `Types.VARCHAR` type code.

The following table lists the valid column definition arguments that you can use in the `defineColumnType` method.

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Table 23-1 Valid Column Type Specifications

If the column has Oracle SQL type:	You can use defineColumnType to define it as:
NUMBER, VARNUM	BIGINT, TINYINT, SMALLINT, INTEGER, FLOAT, REAL, DOUBLE, NUMERIC, DECIMAL, CHAR, VARCHAR
CHAR, VARCHAR2	CHAR, VARCHAR
LONG	CHAR, VARCHAR, LONGVARCHAR
LONGRAW	LONGVARBINARY, VARBINARY, BINARY
RAW	VARBINARY, BINARY
DATE	DATE, TIME, TIMESTAMP, CHAR, VARCHAR
ROWID	ROWID
BLOB	VARBINARY, BINARY
CLOB	LONG, CHAR, VARCHAR

It is always valid to use `defineColumnType` with the original data type of the column.

23.2.3 About Reporting DatabaseMetaData TABLE_REMARKS

The `getColumns`, `getProcedureColumns`, `getProcedures`, and `getTables` methods of the database metadata classes are slow if they must report `TABLE_REMARKS` columns, because this necessitates an expensive outer join. For this reason, the JDBC driver does *not* report `TABLE_REMARKS` columns by default.

You can enable `TABLE_REMARKS` reporting by passing a `true` argument to the `setRemarksReporting` method of an `OracleConnection` object.

Equivalently, instead of calling `setRemarksReporting`, you can set the `remarksReporting` Java property if you use a Java `Properties` object in establishing the connection.

If you are using a standard `java.sql.Connection` object, you must cast it to `OracleConnection` to use `setRemarksReporting`.

The following code snippet illustrates how to enable `TABLE_REMARKS` reporting:

```
((oracle.jdbc.OracleConnection)conn ).setRemarksReporting(true);
```

Here, `conn` is the name of your standard `Connection` object, the following statement enables `TABLE_REMARKS` reporting:

Considerations for getColumns

By default, the `getColumns` method does not retrieve information about the columns if a synonym is specified. To enable the retrieval of information if a synonym is specified, you must call the `setIncludeSynonyms` method on the connection as follows:

```
((oracle.jdbc.OracleConnection)conn ).setIncludeSynonyms(true)
```

This will cause all subsequent `getColumns` method calls on the connection to include synonyms. This is similar to `setRemarksReporting`. Alternatively, you can set the `includeSynonyms` connection property. This is similar to the `remarksReporting` connection property.

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However, bear in mind that if `includeSynonyms` is `true`, then the name of the object returned in the `table_name` column will be the synonym name, if a synonym exists. This is true even if you pass the table name to `getColumns`.

Considerations for getProcedures and getProcedureColumns Methods

According to JDBC versions 1.1 and 1.2, the methods `getProcedures` and `getProcedureColumns` treat the `catalog`, `schemaPattern`, `columnNamePattern`, and `procedureNamePattern` parameters in the same way. In the Oracle definition of these methods, the parameters are treated differently:

- `catalog`

  Oracle does not have multiple catalogs, but it does have packages. Consequently, the `catalog` parameter is treated as the package name. This applies both on input, which is the `catalog` parameter, and the output, which is the `catalog` column in the returned `ResultSet`. On input, the construct " ", which is an empty string, retrieves procedures and arguments without a package, that is, standalone objects. A `null` value means to drop from the selection criteria, that is, return information about both standalone and packaged objects. That is, it has the same effect as passing in the percent sign (%). Otherwise, the `catalog` parameter should be a package name pattern, with SQL wild cards, if desired.

- `schemaPattern`

  All objects within Oracle database must have a schema, so it does not make sense to return information for those objects without one. Thus, the construct " ", which is an empty string, is interpreted on input to mean the objects in the current schema, that is, the one to which you are currently connected. To be consistent with the behavior of the `catalog` parameter, `null` is interpreted to drop the schema from the selection criteria. That is, it has the same effect as passing in `%`. It can also be used as a pattern with SQL wild cards.

- `procedureNamePattern` and `columnNamePattern`

  The empty string (" ") does not make sense for either parameter, because all procedures and arguments must have names. Thus, the construct " " will raise an exception. To be consistent with the behavior of other parameters, `null` has the same effect as passing in percent sign (%).

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24

JDBC Reactive Extensions

The Reactive Extensions are a set of methods that extend the JDBC standard to offer asynchronous database access.

The Reactive Extensions use non-blocking mechanisms for creating connection objects, executing SQL statements, fetching rows, committing transactions, rolling back transactions, closing Connection objects, and reading and writing BFILEs, BLOBs, and CLOBs.

This chapter includes the following topics:

- Overview of JDBC Reactive Extensions
- About Building an Application with Reactive Extensions
- Threading Model of Asynchronous Methods
- About the Flow API
- Using the FlowAdapters Class
- Streaming Row Data with the Reactor Library
- Streaming Row Data with the RxJava Library
- Streaming Row Data with the Akka Streams Library
- Limitations of JDBC Reactive Extensions

24.1 Overview of JDBC Reactive Extensions

The Reactive Extensions implement the Publisher and Subscriber types defined by the `java.util.concurrent.Flow` interfaces, which is the standard JDK representation of a reactive stream.

The Reactive Extensions use a single Java NIO Selector for nonblocking Database operations.

Requirements for Using JDBC Reactive Extensions

For using the JDBC Reactive Extensions, you must use the following:

- JDBC Thin Driver 21c or later for building connections
- JDK 11, or JDK 17 or later
- `ojdbc11.jar` or `ojdbc17.jar`

Architecture of JDBC Reactive Extensions

The following diagram illustrates the architecture of applications using JDBC Reactive Extensions:

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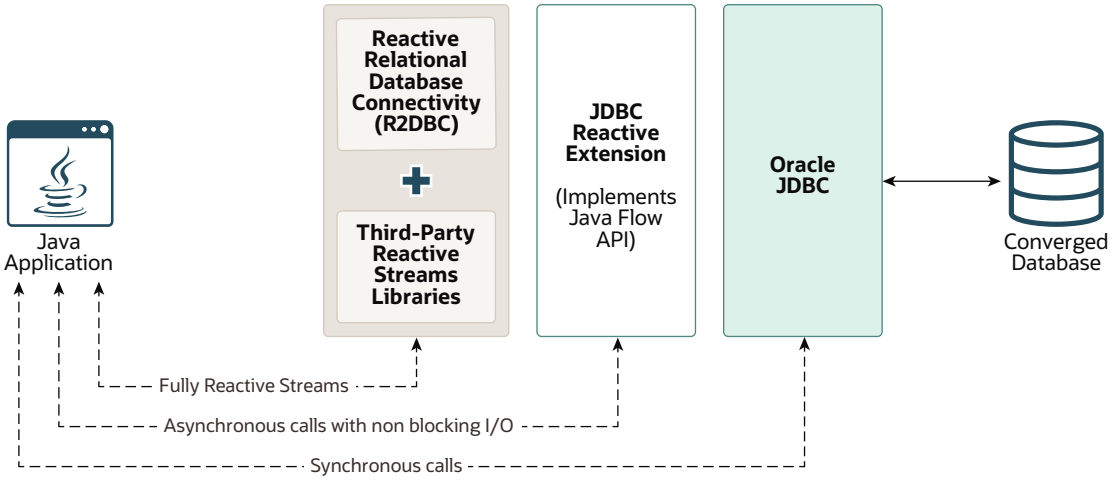
Figure 24-1 Architecture of Applications Using JDBC Reactive Extensions



24.2 About Building an Application with Reactive Extensions

This section describes the steps that you must follow to build an application using the Reactive Extensions.

Building an application using the Reactive Extensions involves the same steps as building an application using the standard methods. But, in case of Reactive Extensions, you use the new asynchronous methods. This section describes how to use the various asynchronous methods in the following sections:

- Opening a Connection Using Asynchronous Methods
- Execution of SQL Statements with Asynchronous Methods
- About Fetching Row Data with Asynchronous Methods
- Reading LOB Data Using Asynchronous Methods
- Writing LOB Data Using Asynchronous Methods
- Committing a Transaction Using Asynchronous Methods
- Closing a Connection Using Asynchronous Methods

24.2.1 Opening a Connection Using Asynchronous Methods

The `OracleConnectionBuilder` interface provides methods for opening a connection asynchronously.

The `OracleConnectionBuilder.buildConnectionPublisherOracle` method returns a `Flow.Publisher<OracleConnection>` type. The Publisher emits a single Connection to a Subscriber. Once the Subscriber signals demand, the Publisher asynchronously opens a new Connection. The Published Connection is identical to a Connection that you can build using the `ConnectionBuilder.build` method.

The following example demonstrates how to asynchronously open a connection.

```
/**
 * Asynchronously opens a new connection
 * @param dataSource Datasource configured with a URL, User, and Password
```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```
   * @return A Publisher that emits a single connection
   * @throws SQLException If a database access error occurs before the
   * connection can be opened
   */
  Flow.Publisher<OracleConnection> openConnection(DataSource dataSource)
    throws SQLException {
    return dataSource.unwrap(OracleDataSource.class)
      .createConnectionBuilder()
      .buildConnectionPublisherOracle();
  }
```

24.2.2 Execution of SQL Statements with Asynchronous Methods

This section describes how to execute SQL statements with asynchronous methods.

The `OraclePreparedStatement` interface exposes methods for asynchronous SQL execution. Each asynchronous method performs a function that is analogous to the corresponding synchronous method of SQL execution. This relationship is expressed in the following table:

Table 24-1 Method Comparison

Synchronous Method	Asynchronous Method
`boolean execute`	`Flow.Publisher<Boolean> executeAsyncOracle`
`long executeLargeUpdate`	`Flow.Publisher<Long> executeUpdateAsyncOracle`
`long[] executeLargeBatch`	`Flow.Publisher<Long> executeBatchAsyncOracle`
`ResultSet executeQuery`	`Flow.Publisher<OracleResultSet> executeQueryAsyncOracle`

The following sections provide more information about the asynchronous methods:

- Standard SQL Statement Execution with the executeAsyncOracle Method
- DML Statement Execution with the executeUpdateAsyncOracle method
- Batch DML Statement Execution with the executeBatchAsyncOracle Method
- SQL Query Execution with the executeQueryAsyncOracle Method

24.2.2.1 Standard SQL Statement Execution with the executeAsyncOracle Method

This section describes the `executeAsyncOracle` method, which is equivalent to the standard `execute` method.

Any type of SQL statement can be executed by calling the `OraclePreparedStatement.executeAsyncOracle` method. This call returns a `Flow.Publisher<Boolean>` type. The Publisher emits a single Boolean and supports multiple Subscribers. If the Boolean value is `TRUE`, then it means that the SQL statement has resulted in row data, which is accessible from the `OraclePreparedStatement.getResultSet` method. If it

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is FALSE, then it means that the SQL statement has returned an update count. The Boolean result is semantically equivalent to the boolean returned by the execute method.

```
/**
 * Asynchronously creates a new table by executing a DDL SQL statement
 * @param connection Connection to a database where the table is created
 * @return A Publisher that emits the result of executing DDL SQL
 * @throws SQLException If a database access error occurs before the DDL
 * SQL can be executed
 */
Flow.Publisher<Boolean> createTable(Connection connection)
  throws SQLException {

  PreparedStatement createTableStatement =
    connection.prepareStatement(
      "CREATE TABLE employee_names (" +
        "id NUMBER PRIMARY KEY, " +
        "first_name VARCHAR(50), " +
        "last_name VARCHAR2(50))");

  Flow.Publisher<Boolean> createTablePublisher =
    createTableStatement.unwrap(OraclePreparedStatement.class)
      .executeAsyncOracle();

  createTablePublisher.subscribe(
    // This subscriber will close the PreparedStatement
    new Flow.Subscriber<Boolean>() {
      public void onSubscribe(Flow.Subscription subscription) {
        subscription.request(1L);
      }
      public void onNext(Boolean item) { }
      public void onError(Throwable throwable) { closeStatement(); }
      public void onComplete() { closeStatement(); }
      void closeStatement() {
        try { createTableStatement.close(); }
        catch (SQLException closeException) { log(closeException); }
      }
    });

  return createTablePublisher;
}
```

24.2.2.2 DML Statement Execution with the executeUpdateAsyncOracle method

This section describes the executeUpdateAsyncOracle method, which is equivalent to the standard executeLargeUpdate method.

You can use the OraclePreparedStatement.executeUpdateAsyncOracle method to execute single (non-batch) DML statements. This call returns a Flow.Publisher<Long> type. The returned publisher emits a single Long value. This Long value indicates the number of rows updated or to be inserted by the DML statement. This Long value result is semantically equivalent to the long value returned by the standard executeLargeUpdate method.

```
/**
 * Asynchronously updates table data by executing a DML SQL statement
```


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```
   * @param connection Connection to a database where the table data resides
   * @return A Publisher that emits the number of rows updated
   * @throws SQLException If a database access error occurs before the DML
   * SQL can be executed
   */
  Flow.Publisher<Long> updateData(Connection connection)
    throws SQLException {

    PreparedStatement updateStatement = connection.prepareStatement(
      "UPDATE employee_names SET " +
        "first_name = UPPER(first_name), " +
        "last_name = UPPER(last_name)");

    Flow.Publisher<Long> updatePublisher =
      updateStatement.unwrap(OraclePreparedStatement.class)
        .executeUpdateAsyncOracle();

    updatePublisher.subscribe(
      // This subscriber will close the PreparedStatement
      new Flow.Subscriber<Long>() {
        public void onSubscribe(Flow.Subscription subscription) {
          subscription.request(1L);
        }
        public void onNext(Long item) { }
        public void onError(Throwable throwable) { closeStatement(); }
        public void onComplete() { closeStatement(); }
        void closeStatement() {
          try { updateStatement.close(); }
          catch (SQLException closeException) { log(closeException); }
        }
      });

    return updatePublisher;
  }
```

24.2.2.3 Batch DML Statement Execution with the executeBatchAsyncOracle Method

This section describes the `executeBatchAsyncOracle` method, which is equivalent to the standard `executeLargeBatch` method.

You can use the `OraclePreparedStatement.executeBatchAsyncOracle` method to execute batch DML statements. This call returns a `Flow.Publisher<Long>` type. The returned publisher emits a `Long` value for each statement in the batch. The `Long` values indicate the number of rows updated by each DML statement. These `Long` value results are semantically equivalent to the `long[]` value returned by the standard `executeLargeBatch` method.

```
  /**
   * Asynchronously loads table data by executing a batch of DML SQL
statements.
   * @param connection Connection to a database where the table data resides.
   * @return A Publisher which emits the number of rows updated.
   * @throws SQLException If a database access error occurs before the DML
   * SQL can be executed.
   */
  Flow.Publisher<Long> createData(
```


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```
  Connection connection, Iterable<Employee> employeeData)
  throws SQLException {

  PreparedStatement batchStatement = connection.prepareStatement(
    "INSERT INTO employee_names (id, first_name, last_name) " +
      "VALUES (?, ?, ?)");

  for (Employee employee : employeeData) {
    batchStatement.setLong(1, employee.id());
    batchStatement.setString(2, employee.firstName());
    batchStatement.setString(3, employee.lastName());
    batchStatement.addBatch();
  }

  Flow.Publisher<Long> batchPublisher =
    batchStatement.unwrap(OraclePreparedStatement.class)
      .executeBatchAsyncOracle();

  batchPublisher.subscribe(
    // This subscriber will close the PreparedStatement
    new Flow.Subscriber<Long>() {
      public void onSubscribe(Flow.Subscription subscription) {
        subscription.request(Long.MAX_VALUE);
      }
      public void onNext(Long item) { }
      public void onError(Throwable throwable) { closeStatement(); }
      public void onComplete() { closeStatement(); }
      void closeStatement() {
        try { batchStatement.close(); }
        catch (SQLException closeException) { log(closeException); }
      }
    });

  return batchPublisher;
}
```

24.2.2.4 SQL Query Execution with the executeQueryAsyncOracle Method

This section describes the `executeQueryAsyncOracle` Method, which is equivalent to the standard `executeQuery` method.

You can execute SQL query statements with the `OraclePreparedStatement.executeQueryAsyncOracle` method. This call returns a `Flow.Publisher<OracleResultSet>` type. The returned publisher emits a single `OracleResultSet` value. The `OracleResultSet` value provides access to row data that is resulted from the SQL query. This `OracleResultSet` is semantically equivalent to the `ResultSet` returned by the standard `executeQuery` method.

```
/**
 * Asynchronously reads table data by executing a SELECT SQL statement
 * @param connection Connection to a database where the table resides
 * @return A Publisher that emits the number of rows updated
 * @throws SQLException If a database access error occurs before the SELECT
 * SQL can be executed
 */
```


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```
  Flow.Publisher<OracleResultSet> readData(Connection connection)
    throws SQLException {

    PreparedStatement queryStatement = connection.prepareStatement(
      "SELECT id, first_name, last_name FROM employee_names");

    Flow.Publisher<OracleResultSet> queryPublisher =
      queryStatement.unwrap(OraclePreparedStatement.class)
        .executeQueryAsyncOracle();

    // Close the PreparedStatement after the result set is consumed.
    queryStatement.closeOnCompletion();

    return queryPublisher;
  }
```

24.2.3 About Fetching Row Data with Asynchronous Methods

This section describes how to fetch row data with asynchronous methods.

The `OracleResultSet` interface exposes the `publisherOracle(Function<OracleRow, T>)` method for asynchronous row data fetching. The argument to this method is a mapping function for row data. The mapping function is applied to each row of the `ResultSet`. The method returns a `Flow.Publisher<T>` type, where T is the output type of the mapping function. The input type of the mapping function is `OracleRow`. An `OracleRow` represents a single row of the `ResultSet`, and exposes methods to access the column values of that row.

The following example demonstrates how you can fetch row data with asynchronous methods:

```
  /**
   * Asynchronously fetches table data by from a ResultSet.
   * @param resultSet ResultSet which fetches table data.
   * @return A Publisher which emits the fetched data as Employee objects.
   * @throws SQLException If a database access error occurs before table data
is
   * fetched.
   */
  Flow.Publisher<Employee> fetchData(ResultSet resultSet)
    throws SQLException {
    // Before closing the ResultSet with publisherOracle(..), first obtain a
    // reference to the ResultSet's Statement. The Statement needs to be
closed
    // after all data has been fetched.
    Statement resultSetStatement = resultSet.getStatement();

    Flow.Publisher<Employee> employeePublisher =
      resultSet.unwrap(OracleResultSet.class)
        .publisherOracle(oracleRow -> {
          try {
            return new Employee(
              oracleRow.getObject("id", Long.class),
              oracleRow.getObject("first_name", String.class),
              oracleRow.getObject("last_name", String.class));
          }
          catch (SQLException getObjectException) {
```


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```
            // Unchecked exceptions thrown by a row mapping function will be
            // emitted to each Subscriber's onError method.
            throw new RuntimeException(getObjectException);
          }
        });

    employeePublisher.subscribe(
      // This subscriber will close the ResultSet's Statement
      new Flow.Subscriber<Employee>() {
        public void onSubscribe(Flow.Subscription subscription) {
          subscription.request(Long.MAX_VALUE);
        }
        public void onNext(Employee item) { }
        public void onError(Throwable throwable) { closeStatement(); }
        public void onComplete() { closeStatement(); }
        void closeStatement() {
          try { resultSetStatement.close(); }
          catch (SQLException closeException) { log(closeException); }
        }
      });

    return employeePublisher;
  }
```

Instances of `OracleRow`, which the mapping function receives as input, becomes invalid after the function returns. Restricting the access of `OracleRow` to the scope of the mapping function enables the driver to efficiently manage the memory that is used to store row data. If you need a persistent copy of an `OracleRow`, then you can use the `OracleRow.clone` method to create a new instance of `OracleRow`, which is backed by a copy of the original `OracleRow` data. The `OracleRow` returned by the `clone` method remains valid outside the scope of the mapping function and retains its data even after the database connection is closed.

The row mapping function must return a non-null value or throw an unchecked exception. If the mapping function throws an unchecked exception, then it is delivered to row data subscribers as an `onError` signal. The row data Publisher supports multiple Subscribers. Row data emission to multiple Subscribers follow certain policies as stated below:

- A Subscriber will not receive an `onNext` signal for row data emitted before the Subscriber received an `onSubscribe` signal.
- A Subscriber will not receive an `onNext` signal until demand has been signaled by all other Subscribers.

The following table demonstrates the event flow while working with multiple subscribers:

Table 24-2 Emission to Multiple Subscribers

Time	Event	Cause
0	SubscriberA receives an `onSubscribe` signal	A call to the row data Publisher's subscribe (Subscriber) method requested a Subscription for SubscriberA
1	SubscriberA requests 1 row	SubscriberA signaled demand on its Subscription

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Table 24-2 (Cont.) Emission to Multiple Subscribers

Time	Event	Cause
2	SubscriberA receives data for the first row of the ResultSets	The row data Publisher fetched a row of data that was requested by SubscriberA
3	SubscriberB receives an `onSubscribe` signal	A call to the row data Publisher's subscribe (Subscriber) method requested a Subscription for SubscriberB
4	SubscriberA requests 1 row	SubscriberA signaled demand on its Subscription
5	SubscriberB requests 1 row	SubscriberB signaled demand on its Subscription
6	Both SubscriberA and SubscriberB receive data for the second row of the ResultSet	The row data Publisher fetched a row of data that was requested by both Subscribers
7	SubscriberA requests 1 row	SubscriberA signaled demand on its Subscription
8	No row data is emitted	The row data Publisher does not emit the next row until *ALL* subscribers have requested it.
9	SubscriberB requests 1 row	SubscriberB signaled demand on its Subscription
10	Both SubscriberA and SubscriberB receive data for the third row of the ResultSet	The row data Publisher fetched a row of data that was requested by both Subscribers

> **Note**
>
> SubscriberB never received data for the first row. This is because SubscriberB subscribed after the first row was emitted. Also, no data was emitted at 8 seconds. This is because all Subscribers need to request the next row before it is emitted. At 8 seconds, SubscriberA had requested for the next row, but SubscriberB had not placed a request till then.

24.2.4 Reading LOB Data Using Asynchronous Methods

The `OracleBlob`, `OracleBFile`, `OracleClob`, and `OracleNClob` interfaces expose a `publisherOracle(long)` method for asynchronous reading of LOB data.

The argument to the `publisherOracle(long)` method is a position of the LOB from where the data is read. The `OracleBlob.publisherOracle(long)` and `OracleBFile.publisherOracle(long)` methods return a Publisher<byte[]> type. This Publisher emits segments of binary data that have been read from the LOB. The `OracleClob.publisherOracle(long)` and `OracleNClob.publisherOracle(long)` methods return a Publisher<String> type. This Publisher emits segments of character data that have been read from the LOB.

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The following example demonstrates how to asynchronously read binary data from a LOB.

```
/**
 * Asynchronously reads binary data from a BLOB
 * @param connection Connection to a database where the BLOB resides
 * @param employeeId ID associated to the BLOB
 * @return A Publisher that emits binary data of a BLOB
 * @throws SQLException If a database access error occurs before the
 * BLOB can be read
 */
Flow.Publisher<byte[]> readLOB(Connection connection, long employeeId)
  throws SQLException {
  PreparedStatement lobQueryStatement = connection.prepareStatement(
    "SELECT photo_bytes FROM employee_photos WHERE id = ?");
  lobQueryStatement.setLong(1, employeeId);

  ResultSet resultSet = lobQueryStatement.executeQuery();
  if (!resultSet.next())
    throw new SQLException("No photo found for employee ID " + employeeId);

  OracleBlob photoBlob =
    (OracleBlob)resultSet.unwrap(OracleResultSet.class).getBlob(1);
  Flow.Publisher<byte[]> photoPublisher = photoBlob.publisherOracle(1);

  photoPublisher.subscribe(
    // This subscriber will close the PreparedStatement and BLOB
    new Flow.Subscriber<byte[]>() {
      public void onSubscribe(Flow.Subscription subscription) {
        subscription.request(Long.MAX_VALUE);
      }
      public void onNext(byte[] item) { }
      public void onError(Throwable throwable) { freeResources(); }
      public void onComplete() { freeResources(); }
      void freeResources() {
        try { lobQueryStatement.close(); }
        catch (SQLException closeException) { log(closeException); }
        try { photoBlob.free(); }
        catch (SQLException freeException) { log(freeException); }
      }
    });
  return photoPublisher;
}
```

You cannot configure the size of data segments emitted by the LOB publishers. The driver chooses a segment size that is optimized as per the `DB_BLOCK_SIZE` parameter of the database.

24.2.5 Writing LOB Data Using Asynchronous Methods

The `OracleBlob`, `OracleClob`, and `OracleNClob` interfaces expose a `subscriberOracle(long)` method for asynchronous writing of LOB data.

The argument to the `subscriberOracle(long)` method is a position of the LOB where the data is written. The `OracleBlob.subscriberOracle(long)` method returns a `Subscriber<byte[]>` type. This Subscriber receives segments of binary data that are written to the LOB. The

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`OracleClob.subscriberOracle(long)` method and the `OracleNClob.subscriberOracle(long)` method return a `Subscriber<String>` type. These Subscribers receive segments of character data that are written to the LOB.

The following examples demonstrate how to asynchronously write binary data to a LOB.

```
  /**
   * Asynchronously writes binary data to a BLOB
   * @param connection Connection to a database where the BLOB resides
   * @param bytesPublisher Publisher that emits binary data
   * @return A CompletionStage that completes with a reference to the BLOB,
   * after all binary data is written.
   * @throws SQLException If a database access error occurs before the table
data is
   * fetched
   */
  CompletionStage<Blob> writeLOB(
    Connection connection, Flow.Publisher<byte[]> bytesPublisher)
    throws SQLException {

    OracleBlob oracleBlob =
      (OracleBlob) connection.unwrap(OracleConnection.class).createBlob();

    // This future is completed after all bytes have been written to the BLOB
    CompletableFuture<Blob> writeFuture = new CompletableFuture<>();

    Flow.Subscriber<byte[]> blobSubscriber =
      oracleBlob.subscriberOracle(1L,
        // This Subscriber will receive a terminal signal when all byte[]'s
        // have been written to the BLOB.
        new Flow.Subscriber<Long>() {
          long totalWriteLength = 0;
          @Override
          public void onSubscribe(Flow.Subscription subscription) {
            subscription.request(Long.MAX_VALUE);
          }
          @Override
          public void onNext(Long writeLength) {
            totalWriteLength += writeLength;
            log(totalWriteLength + " bytes written.");
          }
          @Override
          public void onError(Throwable throwable) {
            writeFuture.completeExceptionally(throwable);
          }
          @Override
          public void onComplete() {
            writeFuture.complete(oracleBlob);
          }
        });

    bytesPublisher.subscribe(blobSubscriber);
    return writeFuture;
  }
```


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The `OracleBlob`, `OracleClob`, and `OracleNClob` interfaces also expose a `subscriberOracle(long, Subscriber<Long>)` method that performs the same function as the single-argument form of the `subscriberOracle(long)` method. However, the single-argument form also accepts a `Subscriber<Long>` type. The `Subscriber<Long>` type notifies a Subscriber to receive the result of write operations against the database. Each time an asynchronous write operation completes, the `Subscriber<Long>` type receives an `onNext` signal with the number of bytes or number of characters written by the operation. If an asynchronous write operation fails, the `Subscriber<Long>` type receives an `onError` signal. After the final write operation completes, the `Subscriber<Long>` receives an `onComplete` signal.

After the `CompletionStage<Blob>` returned by the `writeLOB` method completes, the resulting Blob object can be passed to the `insertLOB` method to have the BLOB data stored in a table.

The following examples demonstrate how to insert the data.

```
/**
 * Asynchronously inserts BLOB data into a table by executing a DML SQL
 * statement
 * @param connection Connection to a database where the table data resides
 * @param employeeId ID related to the BLOB data
 * @param photoBlob Reference to BLOB data
 * @return A Publisher that emits the number of rows inserted (always 1)
 * @throws SQLException If a database access error occurs before the DML
 * SQL can be executed
 */
Flow.Publisher<Long> insertLOB(
  Connection connection, long employeeId, Blob photoBlob)
  throws SQLException {

  PreparedStatement lobInsertStatement = connection.prepareStatement(
    "INSERT INTO employee_photos(id, photo_bytes) VALUES (? ,?)");
  lobInsertStatement.setLong(1, employeeId);
  lobInsertStatement.setBlob(2, photoBlob);

  Flow.Publisher<Long> insertPublisher =
    lobInsertStatement.unwrap(OraclePreparedStatement.class)
      .executeUpdateAsyncOracle();

  insertPublisher.subscribe(new Flow.Subscriber<Long>() {
    @Override
    public void onSubscribe(Flow.Subscription subscription) {
      subscription.request(1L);
    }
    @Override
    public void onNext(Long item) { }
    @Override
    public void onError(Throwable throwable) { releaseResources(); }
    @Override
    public void onComplete() { releaseResources(); }
    void releaseResources() {
      try { lobInsertStatement.close(); }
      catch (SQLException closeException) { log(closeException); }
      try { photoBlob.free(); }
      catch (SQLException freeException) { log(freeException); }
    }
  });
```


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```
    return insertPublisher;
  }
```

24.2.6 Committing a Transaction Using Asynchronous Methods

The `OracleConnection` interface exposes the `commitAsyncOracle` and `rollbackAsyncOracle` methods for asynchronous transaction completion.

Both the `commitAsyncOracle` and `rollbackAsyncOracle` methods return a `Flow.Publisher<Void>` type. The Publishers do not emit any item, as signified by their `<Void>` type. The Publishers emit a single `onComplete` or `onError` signal to indicate whether the commit or rollback operation was completed successfully or not.

The following example demonstrates how to asynchronously commit a transaction.

```
/**
 * Asynchronously commits a transaction
 * @param connection Connection to a database with an active transaction
 * @return A Publisher that emits a terminal signal when the transaction
 * has been committed
 * @throws SQLException If a database access error occurs before the
 * transaction can be committed
 */
public Flow.Publisher<Void> commitTransaction(Connection connection)
  throws SQLException {
  return connection.unwrap(OracleConnection.class)
    .commitAsyncOracle();
}
```

The `commitAsyncOracle` and `rollbackAsyncOracle` methods perform the same function as the `Connection.commit` and `Connection.rollback` methods.

24.2.7 Closing a Connection Using Asynchronous Methods

The `OracleConnection` interface exposes the `closeAsyncOracle` method for closing an asynchronous connection.

The `closeAsyncOracle` method returns a `Flow.Publisher<Void>` type. The Publisher does not emit any item, as signified by its `<Void>` type. The Publisher emits a single `onComplete` or `onError` signal to indicate whether the connection was closed successfully or not.

The following example demonstrates how to asynchronously close a connection.

```
/**
 * Asynchronously closes a connection
 * @param connection Connection to be closed
 * @return A Publisher that emits a terminal signal when the connection
 * has been closed
 * @throws SQLException If a database access error occurs before the
 * connection can be closed
 */
Flow.Publisher<Void> closeConnection(Connection connection)
  throws SQLException {
  return connection.unwrap(OracleConnection.class)
```


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```
        .closeAsyncOracle();
}
```

The `closeAsyncOracle` method performs the same function as the `Connection.close` method.

24.3 Threading Model of Asynchronous Methods

This section describes the threading model of asynchronous methods.

When an asynchronous method is called, it performs as much work as possible on the calling thread, without blocking on a network read. An asynchronous method call returns immediately after a request is written to the network, without waiting for a response. If the write buffer of the operating system is not large enough to store a complete request, then the calling thread may become blocked until this buffer is flushed.

Once the write job is complete, the network channel is registered for I/O readiness polling. A single thread polls the network channels of all Oracle JDBC Connections in the same JVM. The I/O polling thread is named `oracle.net.nt.TcpMultiplexer`, and is configured as a daemon thread. This polling thread performs a blocking operation using a Selector.

When I/O readiness is detected for a network channel, the polling thread arranges for a worker thread to handle the event. The worker thread reads from the network and then notifies a Publisher that an operation is complete. Upon notification, the Publisher arranges worker threads that emit a signal to each of its Subscribers.

The `java.util.concurrent.Executor` interface manages the worker threads. The default Executor is the `java.util.concurrent.ForkJoinPool.commonPool` method. You can call the `OracleConnectionBuilder.executorOracle(Executor)` method to specify an alternative Executor.

24.4 About the Flow API

The `java.util.concurrent.Flow` types define the minimal set of operations that you can use to create a reactive stream.

You can write application code directly against the Flow API. However, you must implement the low-level signal processing in accordance with the reactive-streams specification as specified in the following link

https://github.com/reactive-streams/reactive-streams-jvm/blob/master/README.md

The JDBC Reactive Extensions APIs handle the low-level mechanics of the Flow API to the application using `java.util.concurrent.Flow.Publisher` and `java.util.concurrent.Flow.Subscriber`. Popular libraries such as Reactor, RxJava, and Akka-Streams interface with the `org.reactivestreams.Publisher` and `org.reactivestreams.Subscriber` types defined by the `reactive-streams-jvm` project as specified in the following link:

https://github.com/reactive-streams/reactive-streams-jvm/tree/master/api/src/main/java/org/reactivestreams

Although the `org.reactivestreams.Publisher` type and the `org.reactivestreams.Subscriber` type, and their `java.util.concurrent.Flow` counterparts declare the same interface, the Java compiler must still consider them to be distinct types. You can convert between the Flow type and the `org.reactivestreams` type using the `org.reactivestreams.FlowAdapters` class as specified in the following link

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https://github.com/reactive-streams/reactive-streams-jvm/tree/master/api/src/main/java9/org/reactivestreams

Oracle recommends that you use the reactive streams libraries when interfacing with the Flow types exposed by the JDBC driver.

24.5 Using the FlowAdapters Class

The libraries covered in this section interfaces with the `org.reactivestreams` types described in the **About the Flow API** section.

The following code snippet shows how the `FlowAdapters` class can convert the `Flow.Publisher` types into the `org.reactivestreams` types.

Example 24-1 Conversion to org.reactivestreams Types

```
public static org.reactivestreams.Publisher<ResultSet> publishQuery(
  PreparedStatement queryStatement) {
  try {
    Flow.Publisher<OracleResultSet> queryPublisher =
      queryStatement.unwrap(OraclePreparedStatement.class)
        .executeQueryAsyncOracle();

    return FlowAdapters.toPublisher(queryPublisher);
  }
  catch (SQLException sqlException) {
    return createErrorPublisher(sqlException);
  }
}

public static <T> org.reactivestreams.Publisher<T> publishRows(
  ResultSet resultSet, Function<OracleRow, T> rowMappingFunction) {
  try {
    Flow.Publisher<T> rowPublisher =
      resultSet.unwrap(OracleResultSet.class)
        .publisherOracle(rowMappingFunction);

    return FlowAdapters.toPublisher(rowPublisher);
  }
  catch (SQLException sqlException) {
    return createErrorPublisher(sqlException);
  }
}
```

24.6 Streaming Row Data with the Reactor Library

The Reactor library defines a *Flux* type that represents a stream of many items and a *Mono* type that represents a stream of just one item.

The following example shows how to create a *Flux* of row data using the Reactive Extensions.

```
      private Publisher<Employee> queryAllEmployees(Connection connection) {

      return Flux.using(
```


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```
            // Prepare a SQL statement.
            () -> connection.prepareStatement("SELECT * FROM emp"),

            // Execute the PreparedStatement.
            preparedStatement ->
              // Create a Mono which emits one ResultSet.
              Mono.from(publishQuery(preparedStatement))
                // Flat map the ResultSet to a Flux which emits many Rows. Each
row
                // is mapped to an Employee object.
                .flatMapMany(resultSet ->
                  publishRows(resultSet, row -> mapRowToEmployee(row))),

            // Close the PreparedStatement after emitting the last Employee object
            prepareStatement -> {
              try {
                prepareStatement.close();
              }
              catch (SQLException sqlException) {
                throw new RuntimeException(sqlException);
              }
            });
    }
```

The `using` factory method creates a *Flux* that depends on a resource that must be released explicitly. In this case, the resource is a `PreparedStatement` instance that is released by calling the `close` method.

The first lambda argument creates the `PreparedStatement` instance. This lambda is executed before the *Flux* begins to emit items.

The second lambda argument uses the `PreparedStatement` instance to create a stream of row data that is mapped to an **Employee** object. First, the `PreparedStatement` instance is executed by the call to the `publishQuery` method. As the query execution Publisher emits a single `ResultSet`, it is adapted into a *Mono*. Once the query execution completes, the *Mono* emits the `ResultSet` into the lambda specified by the `flatMapMany` method. This lambda calls

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the `publishRows` method with a function to map `OracleRow` objects into the **Employee** objects. This results in the `flatMapMany` method call returning a `Flux` of **Employee** objects, where each **Employee** is mapped from a row of the `ResultSet` object.

The third lambda argument closes the `PreparedStatement` instance. This lambda is executed after the *Flux* emits its last item.

24.7 Streaming Row Data with the RxJava Library

The RxJava library defines a *Flowable* type that represents a stream of many items, and a *Single* type that represents a stream of just one item.

The following example shows how to create a *Flowable* of row data using the Reactive Extensions.

```
    private Publisher<Employee> queryAllEmployees(Connection connection) {

      return Flowable.using(

        // Prepare a SQL statement

        () -> connection.prepareStatement("SELECT * FROM emp"),


        // Execute the PreparedStatement

        queryStatement ->

          // Create a Single which emits one ResultSet

          Single.fromPublisher(publishQuery(queryStatement))

            // Flat map the ResultSet to a Flowable which emits many rows,
where

            // each row is mapped to an Employee object

            .flatMapPublisher(resultSet ->

              publishRows(resultSet, oracleRow ->
mapRowToEmployee(oracleRow))),


        // Close the PreparedStatement after emitting the last Employee object

        PreparedStatement::close

      );

    }
```

The `using` factory method creates a *Flowable* that depends on a resource that must be released explicitly. In this case, the resource is a `PreparedStatement` instance that is released by calling the `close` method.

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The first lambda argument creates the `PreparedStatement` instance. This lambda is executed before the *Flowable* begins to emit items.

The second lambda argument uses the `PreparedStatement` instance to create a stream of row data that is mapped to an **Employee** object. First, the `PreparedStatement` instance is executed by the `publishQuery` method call. As the query execution Publisher emits a single `ResultSet` object, it is adapted into a *Single*. Once the query execution completes, the *Single* emits the `ResultSet` object into the lambda specified by the `flatMapPublisher` method. This lambda calls the `publishRows` method with a function to map `OracleRow` objects into **Employee** objects. This results in the `flatMapPublisher` method call returning a *Flowable* of **Employee** objects, where each **Employee** is mapped from a row of the `ResultSet`.

The third method handle argument closes the `PreparedStatement` instance. This lambda is executed after the *Flowable* emits its last item.

24.8 Streaming Row Data with the Akka Streams Library

The Akka Streams library defines a *Source* type that represents a stream of items.

The following example shows how to create a *Source* of row data using the Reactive Extensions.

```
    private Source<Employee, NotUsed> queryAllEmployees(Connection
connection) {


      final PreparedStatement queryStatement;

      try {

        queryStatement = connection.prepareStatement("SELECT * FROM emp");

      }

      catch (SQLException prepareStatementFailure) {

        return Source.failed(prepareStatementFailure);

      }


      // Create a Source which emits one ResultSet

      return Source.fromPublisher(publishQuery(queryStatement))

        // Flat map the ResultSet to a Source which emits many Rows, where
each

        // Row is mapped to an Employee object

        .flatMapConcat(resultSet -> {

          Publisher<Employee> employeePublisher =

            publishRows(resultSet, oracleRow -> mapRowToEmployee(oracleRow));
```


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```
            return Source.fromPublisher(employeePublisher);

        })

        // This Sink closes the PreparedStatement when the Source terminates

        .alsoTo(Sink.onComplete(result -> queryStatement.close()));

    }
```

A `PreparedStatement` instance is used to create a stream of row data that is mapped to an **Employee** object. First, the `PreparedStatement` instance is executed by the `publishQuery` method call. The query execution Publisher emits a single `ResultSet` object. This Publisher is adapted into a *Source*. Once the query completes, the *Source* emits the `ResultSet` object into the lambda specified by the `flatMapConcat` method.

This lambda calls the `publishRows` method with a function to map `OracleRow` objects into **Employee** objects. This results in the `flatMapConcat` method call returning a *Source* of **Employee** objects, where each **Employee** is mapped from a row of the `ResultSet` object.

The `PreparedStatement` instance is a resource that needs to be explicitly closed. This is handled by the `alsoTo` method call that specifies a *Sink* that closes the `PreparedStatement` instance when the *Source* emits an `onComplete` or `onError` signal.

24.9 Limitations of JDBC Reactive Extensions

This section describes the limitations of JDBC Reactive Extensions.

JDBC Reactive Extensions have the following limitations:

- You must access the asynchronous methods through the `java.sql.Wrapper.unwrap` method, instead of accessing those through a type cast. This ensures correct behavior of the asynchronous methods when you use them with proxy Oracle JDBC classes, for example, when you use asynchronous methods with connection pools.
- Reading large responses from the network may require blocking I/O bound operations. Blocking read operations can occur if the driver reads a response that is larger than the TCP Receive buffer size.
- Asynchronous SQL execution supports neither scrollable `ResultSet` types nor sensitive `ResultSet` types.

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25

Support for Java library for Reactive Streams Ingestion

Starting with Oracle Database Release 21c, you have a Java library that provides support for Reactive Streams Ingestion (RSI), which enables efficient streaming of data into Oracle Database. The new Java library enables Java applications to continuously receive and ingest data from a large group of clients.

Using the direct path load method of Oracle Database for inserting data, the new Java library makes the ingestion process nonblocking and extremely fast. It uses an extension of the existing UCP APIs, which enables the ingestion process to furnish several high-availability and scalability features of the database, like support for table partitions, Oracle RAC connection affinity, and sharding.

25.1 Overview of the Java Library for Reactive Streams Ingestion

The Java library for Reactive Streams Ingestion (RSI) enables efficient data streaming into Oracle Database in a nonblocking way.

This library is particularly useful when a large number of clients use the database to persist information in the form of table rows, and do not want to be blocked waiting for a synchronous response from the database. So, in case of use cases like the following, when the application must ingest streaming data into the database at a very high speed, and persist it in the form of rows in an Oracle Database table, you can use this library:

- Internet of Things (IoT) sensors
- Time series data for stock trade
- Call detail records (CDRs)
- Geospatial activities
- Video web sites
- Social media posts

For using this library, you must add the following `JAR` files to your `CLASSPATH`:

- `rsi.jar`
- `ojdbc11.jar` or `ojdbc17.jar`
- `ucp.jar`
- `ons.jar`

25.2 Features of the Java Library for Reactive Streams Ingestion

The Java library for Reactive Streams Ingestion (RSI) uses the direct path load method of Oracle Database for inserting data. It also uses Oracle Universal Connection Pool (UCP) to furnish several high-availability and scalability features of the Database, such as support for table partitions, Oracle RAC connection affinity, and sharding. So, this library provides the benefits of the following features:

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- Reactive Streams Ingestion
- Direct Path Load
- Universal Connection Pool

25.2.1 Reactive Streams Ingestion

This is the core feature of the Java library for Reactive Streams Ingestion, which provides the APIs to handle the logic.

The library implements the `Java.util.concurrent.Flow` Subscriber interface. You must implement the `Java.util.concurrent.Flow` Publisher interface for invoking the methods of the Subscriber interface. The Subscriber interface has the following methods:

- `onSubscribe`
  Invoke this method only once for establishing the initial relationship between the Subscriber interface and the Publisher interface.
- `onNext`
  Invoke this method for creating each new row in the implementation of the Subscriber interface that the library provides.
- `onError`
  Invoke this method in case of any error that might occur during the ingestion process.
- `onComplete`
  Invoke this method when the ingestion job completes.

The Subscriber interface calls the `request(n)` method or the `cancel` method of the `Java.util.concurrent.Flow` Subscriber interface to indicate whether it can accept more data or it should stop ingesting data.

> **See Also**
>
> The Java.util.concurrent.Flow Subscriber Interface

25.2.2 Direct Path Load

The Java library for Reactive Streams Ingestion uses the direct path load method of Oracle Database for nonblocking data ingestion. This method eliminates the SQL layer overhead significantly as it formats Oracle data blocks and writes the data blocks directly to the database files.

> **See Also**
>
> The Direct Path Load Method

During the direct path load method call, the database appends the inserted data after the existing data in the table. This method writes data directly into data files, bypassing the buffer cache. It does not perform reuse of free space in the table, and ignores the referential integrity constraints. So, a direct path load method can perform significantly better than conventional insert operations.

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25.2.3 Universal Connection Pool

The Java library for Reactive Streams Ingestion (RSI) uses Universal Connection Pool (UCP) for various connection pooling and management activities like sharding topology knowledge, Fast Application Notification (FAN) awareness for an Oracle Real Application Cluster (Oracle RAC) database, and so on.

The RSI library uses the UCP sharding APIs to establish a proper connection for the specified sharding key. You can map each record in RSI to a unique chunk ID and then use the unique chunk ID to group these records together. When the RSI library has enough records to send to the database, then it borrows a chunk specific connection from UCP and uses that connection to insert the record into the sharded database.

25.3 About Reactive Streams Ingestion (RSI) Modes

The current release introduces the new DataLoad mode, which is useful when you use the Java library for Reactive Streams Ingestion (RSI) to execute a large `INSERT` batch to the database.

Starting from Oracle Database 23ai Release, you can use the Java library for Reactive Streams Ingestion (RSI) in the following modes, depending on your business use case:

- **The Streaming mode:** Use this default mode, when you want to use RSI in a server where the number of rows to be inserted is not finite, but you do not need to insert a large number of rows at one go.
- **The DataLoad Mode:** Use the DataLoad mode, when there is a known large list of records to be inserted to the database at one go.

The key differences between the DataLoad mode and the Streaming mode are:

- In the DataLoad mode, the changes are not committed until the RSI instance is closed. In the default Streaming mode, the changes are committed regularly. This can negatively impact the throughput, when you execute a large `INSERT` batch to the database.
- In the DataLoad mode, each worker thread has its own JDBC connection. So, there is no effort to reduce the number of JDBC connections needed to execute the insertion task. This behavior is different from the default Streaming mode, where the worker threads share a pool of JDBC connections.

25.3.1 Enabling the DataLoad Mode

The Streaming mode is enabled by default with the Java library for Reactive Streams Ingestion. To enable the DataLoad mode, you must use the `useDataLoadMode` method.

Enable the DataLoad mode as shown in the following code snippet:

```
ReactiveStreamsIngestion.Builder rsiBuilder =
ReactiveStreamsIngestion.builder()
    .useDataLoadMode()
    .username("<user_name>")
    .password("<password>")
    .url("jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
(HOST=myhost.com)(PORT=5521))(CONNECT_DATA=(SERVICE_NAME=myservice.com)))")
    .table("customers")
    .columns (new String[] { "id", "name", "region" });
```


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```
// Use try-with-resource statement to ensure that RSI instance is closed at
the
// end of the statement.
try (ReactiveStreamsIngestion rsi = rsiBuilder.build()){
   // Publish Records.
}
```

25.4 Code Samples: Java Library for Reactive Streams Ingestion

This section contains code samples showing how to use the Reactive Streams Ingestion library.

- PushPublisher
- Flow.Publisher Dynamic Implementations
- Flow.Publisher Third-Party implementations

25.4.1 PushPublisher

This is the simplest way to use the Reactive Streams Ingestion (RSI) library, where the RSI library implements the `java.util.concurrent.Flow.Subscriber` interface and the Java code in your application implements the `java.util.concurrent.Flow.Publisher` interface.

The following example demonstrates this implementation, where you create a Publisher and the RSI library subscribes to that Publisher:

Example 25-1 PushPublisher

```
package oracle.rsi.demos;
import java.sql.SQLException;
import java.time.Duration;
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;

import oracle.rsi.ReactiveStreamsIngestion;
import oracle.rsi.PushPublisher;

public class SimplePushPublisher {

  public static void main(String[] args) throws SQLException {

    ExecutorService workerThreadPool = Executors.newFixedThreadPool(2);

    ReactiveStreamsIngestion rsi = ReactiveStreamsIngestion
        .builder()
        .url(
            "jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
(HOST=example.com)(PORT=5521))(CONNECT_DATA=(SERVICE_NAME=myservice.com)))")
        .username(<user_name>)
        .password(<password>)
        .schema(<schema_name>)
        .executor(workerThreadPool)
        .bufferRows(10)
        .bufferInterval(Duration.ofSeconds(20))
        .table("customers")
```


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```
        .columns(new String[] { "id", "name", "region" })
        .build();

    PushPublisher<Object[]> pushPublisher =
ReactiveStreamsIngestion.pushPublisher();
    pushPublisher.subscribe(rsi.subscriber());

    //Ingests byte arrays using the accept method
    pushPublisher.accept(new Object[] { 1, "John Doe", "North" });
    pushPublisher.accept(new Object[] { 2, "Jane Doe", "North" });
    pushPublisher.accept(new Object[] { 3, "John Smith", "South" });

    try {
      pushPublisher.close();
    } catch (Exception e) {
      // TODO Auto-generated catch block
      e.printStackTrace();
    }

    rsi.close();

    workerThreadPool.shutdown();

  }

}
```

25.4.2 Flow.Publisher Dynamic Implementations

The following example shows how to use the RSI library when your application implements the Flow.Publisher interface and subscribes to the library.

Example 25-2 Flow.Publisher Dynamic Implementations

```
package oracle.rsi.demos;
import java.sql.SQLException;
import java.time.Duration;
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;
import java.util.concurrent.Flow.Publisher;
import java.util.concurrent.Flow.Subscriber;
import java.util.concurrent.Flow.Subscription;
import java.util.function.Consumer;

import oracle.rsi.ReactiveStreamsIngestion;

public class SimpleFlowPublisher {

  public static void main(String[] args) throws SQLException {

    ExecutorService workerThreadPool = Executors.newFixedThreadPool(2);

    ReactiveStreamsIngestion rsi = ReactiveStreamsIngestion
        .builder()
        .url(
```


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```
            "jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
(HOST=example.com)(PORT=5521))(CONNECT_DATA=(SERVICE_NAME=myservice.com)))")
        .username(<user_name>)
        .password(<password>)
        .schema(<schema_name>)
        .executor(workerThreadPool)
        .bufferRows(1)
        .bufferInterval(Duration.ofMinutes(60))
        .table("customers")
        .columns(new String[] { "id", "name", "region" })
        .build();

    SimpleObjectPublisher<Object[]> publisher = new
SimpleObjectPublisher<Object[]>();
    publisher.subscribe(rsi.subscriber());

    SimpleObjectPublisher<Object[]> anotherPublisher = new
SimpleObjectPublisher<Object[]>();
    anotherPublisher.subscribe(rsi.subscriber());

    publisher.accept(new Object[] { 1, "John Doe", "North" });
    publisher.accept(new Object[] { 2, "Jane Doe", "North" });
    publisher.accept(new Object[] { 3, "John Smith", "South" });

    anotherPublisher.accept(new Object[] { 4, "John Doe", "North" });
    anotherPublisher.accept(new Object[] { 5, "Jane Doe", "North" });
    anotherPublisher.accept(new Object[] { 6, "John Smith", "South" });

    rsi.close();

    workerThreadPool.shutdown();

  }

}

class SimpleObjectPublisher<T> implements Publisher<T>, Consumer<T> {

  Subscriber<? super T> subscriber;

  Subscription subscription = new SimpleObjectSubscription();

 //Data streaming starts

  @Override
  public void subscribe(Subscriber<? super T> subscriber) {
    this.subscriber = subscriber;
    this.subscriber.onSubscribe(subscription);
  }

  @Override
  public void accept(T t) {
    subscriber.onNext(t);
  }

}
```


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```
 // You must provide this subscription
class SimpleObjectSubscription implements Subscription {

  @Override
  public void request(long n) {
    System.out.println("Library requesting: " + n + " records");
  }

  @Override
  public void cancel() {
    // TODO Auto-generated method stub
  }

}
```

25.4.3 Flow.Publisher Third-Party implementations

The following example shows how to use the RSI library when a third-party implements the Flow.Publisher interface.

In the following example, the standard JDK `SubmissionPublisher` interface is the third-party interface.

Example 25-3 Flow.Publisher Third-Party Implementations

```
package oracle.rsi.demos;
import java.sql.SQLException;
import java.time.Duration;
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;
import java.util.concurrent.SubmissionPublisher;

import oracle.rsi.ReactiveStreamsIngestion;

public class SimpleSubmissionPublisher {

  public static void main(String[] args) throws SQLException {

    ExecutorService workerThreadPool = Executors.newFixedThreadPool(2);

    ReactiveStreamsIngestion rsi = ReactiveStreamsIngestion
        .builder()
        .url(
            "jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
(HOST=example.com)(PORT=5521))(CONNECT_DATA=(SERVICE_NAME=myservice.com)))")
        .username(<user_name>)
        .password(<password>)
        .schema(<schema_name>)
        .executor(workerThreadPool)
        .bufferRows(10)
        .bufferInterval(Duration.ofSeconds(20))
        .table("customers")
        .columns(new String[] { "id", "name", "region" })
        .build();
```


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```
    SubmissionPublisher<Object[]> publisher = new SubmissionPublisher<>();
    publisher.subscribe(rsi.subscriber());

    publisher.submit(new Object[] { 1, "John Doe", "North" });
    publisher.submit(new Object[] { 2, "Jane Doe", "North" });
    publisher.submit(new Object[] { 3, "John Smith", "South" });

    while (publisher.estimateMaximumLag() > 0);

    try {
      publisher.close();
    } catch (Exception e) {
      // TODO Auto-generated catch block
      e.printStackTrace();
    }

    rsi.close();

    workerThreadPool.shutdown();

  }

}
```

25.5 Limitations of Java library for Reactive Streams Ingestion

Reactive streams ingestion of data streams may not ingest all the data into the database in case of unexpected crashes or errors because the library may lose some of the records while trying to store them in the database.

Apart from the possibility of data loss due to database crashes, this library has the following limitations:

- It does not support database triggers.
- It does not check referential integrity.
- It does not support clustered tables.
- It does not support loading of remote objects.
- It does not support loading of `VARRAY` columns.
- It does not support `LONG` data type with streams.
- It expects the `LONG` data type to be the last column in the database table.
- It expects all partitioning columns to appear before any column with `LOB` data type.

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26

Support for Pipelined Database Operations

Java applications can now asynchronously submit several SQL requests to the server without waiting for the return of the preceding calls.

This chapter discusses more about pipelining in the following topics:

- Overview of Pipelining
- JDBC Support for Pipelining
- Pipelining with Reactive Extensions
- Pipelining with Java library for Reactive Streams Ingestion

26.1 Overview of Pipelining

Pipelining is a form of network communication in which an application can send multiple requests to a server, without having to wait for a response.

The fundamental idea of pipelining is to keep the server busy and enable an application to use the interleaving requests appropriately. The application can keep sending requests, while the server builds up a queue and processes those requests one by one. Then, the server sends the responses back to the client in the same order in which it received the requests.

As the pipeline does not read responses very often, using the data from a previous SQL response as in-bind data to the subsequent request creates a dependency and breaks the pipeline. So, the application must ensure that the requests are independent because it is an essential requirement for the pipelining functionality.

Pipelining offers the following benefits to your applications:

- Improved response time and throughput
- Improved scalability due to reduced context switching

26.2 JDBC Support for Pipelining

In the previous releases, the JDBC driver did not allow a new database call to start until the current call had been completed. Starting with Oracle Database Release 23ai, JDBC Thin drivers now support pipelined database operations.

As a pipeline is executed by sending multiple requests without waiting for a response, this feature translates to an asynchronous programming model, in which the execution of multiple SQL statements can begin even before a thread consumes the results of those statements.

You can implement pipelining in your JDBC applications, using the following asynchronous programming features of Oracle Database:

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> **Note**
>
> When calls are made to a reactive (asynchronous) API or a standard JDBC batching API, pipelining is enabled by default.

- Pipelining with Reactive Extensions
- Pipelining with Java library for Reactive Streams Ingestion

26.3 Pipelining with Reactive Extensions

Starting from Oracle Database Relese 23ai, you can use the Reactive Extensions APIs to carry out pipelined database operations.

The following code provides a simplified example of how you can use the Reactive Extensions APIs to carry out a pipeline:

In the following example, a call to the `unwrap(OraclePreparedStatement.class)` method is used to access the `executeUpdateAsyncOracle` and `executeQueryAsyncOracle` methods. These methods return a `Flow.Publisher` that implements the Reactive Streams specification. As the result of each SQL statement is received, the corresponding Publisher signals that result to a Subscriber.

```
...
void pipelineExample(OracleConnection connection) throws SQLException {

  // Prepare statements to execute
  PreparedStatement delete = connection.prepareStatement(
    "DELETE FROM example WHERE id = 0");
  PreparedStatement insert = connection.prepareStatement(
    "INSERT INTO example (id, value) VALUES (1, 'x')");
  PreparedStatement select = connection.prepareStatement(
    "SELECT id, value FROM example WHERE id = 2");

  // Execute statements in a pipeline
  Flow.Publisher<Long> deletePublisher =
    delete.unwrap(OraclePreparedStatement.class)
      .executeUpdateAsyncOracle();
  Flow.Publisher<Long> insertPublisher =
    insert.unwrap(OraclePreparedStatement.class)
      .executeUpdateAsyncOracle();
  Flow.Publisher<OracleResultSet> selectPublisher =
    select.unwrap(OraclePreparedStatement.class)
      .executeQueryAsyncOracle();
...
}
```


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26.4 Pipelining with Java library for Reactive Streams Ingestion

Starting from Oracle Database Relese 23ai, you can use the Java library for Reactive Streams Ingestion to carry out pipelined database operations.

The following code provides a simplified example of how you can use the Java library for Reactive Streams Ingestion to carry out a pipeline:

In the following example, instances of `Mono` and `Flux` publishers are created by calling their `from` methods. The argument to the method is an `org.reactivestreams.Publisher`, which is adapted from a `Flow.Publisher`, by calling `org.reactivestreams.FlowAdapters.toPublisher`. A subscribe method is called to asynchronously consume results with a callback function. To consume a result of multiple rows, a call to `Mono.flatMapMany` converts a stream of a single `ResultSet` into a stream of multiple row values.

```
import oracle.jdbc.OracleConnection;
import oracle.jdbc.OraclePreparedStatement;
import oracle.jdbc.OracleResultSet;
import org.reactivestreams.FlowAdapters;
import org.reactivestreams.Publisher;
import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.concurrent.CompletionException;
import java.util.concurrent.Flow;

public class ReactiveExample {

  void reactivePipelineExample(OracleConnection connection) throws
SQLException {

    // Push a DELETE into the pipeline
    Mono.using(
        () -> connection.prepareStatement("DELETE FROM example WHERE id = 1"),
        preparedStatement -> Mono.from(publishUpdate(preparedStatement)),
        preparedStatement -> close(preparedStatement))
      .subscribe(deleteCount ->
        System.out.println(deleteCount + " rows deleted"));

    // Push an INSERT operation into the pipeline
    Mono.using(
        () -> connection.prepareStatement(
          "INSERT INTO example (id, value) VALUES (1, 'x')"),
        preparedStatement -> Mono.from(publishUpdate(preparedStatement)),
        preparedStatement -> close(preparedStatement))
      .subscribe(insertCount ->
        System.out.println(insertCount + " rows inserted"));

    // Push a SELECT into the pipeline
    Flux.using(
        () -> connection.prepareStatement(
```


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```
            "SELECT id, value FROM example ORDER BY id"),
          preparedStatement ->
            Mono.from(publishQuery(preparedStatement))
              .flatMapMany(resultSet -> publishRows(resultSet)),
          preparedStatement -> close(preparedStatement))
        .subscribe(rowString ->
          System.out.println(rowString));
    }
    Publisher<Long> publishUpdate(PreparedStatement preparedStatement) {
      try {
        Flow.Publisher<Long> updatePublisher =
          preparedStatement.unwrap(OraclePreparedStatement.class)
            .executeUpdateAsyncOracle();

        return FlowAdapters.toPublisher(updatePublisher);
      }
      catch (SQLException sqlException) {
        return Mono.error(sqlException);
      }
    }

    Publisher<OracleResultSet> publishQuery(PreparedStatement
  preparedStatement) {
      try {
        Flow.Publisher<OracleResultSet> queryPublisher =
          preparedStatement.unwrap(OraclePreparedStatement.class)
            .executeQueryAsyncOracle();

        return FlowAdapters.toPublisher(queryPublisher);
      }
      catch (SQLException sqlException) {
        return Mono.error(sqlException);
      }
    }

    Publisher<String> publishRows(ResultSet resultSet) {
      try {
        Flow.Publisher<String> rowPublisher =
          resultSet.unwrap(OracleResultSet.class)
            .publisherOracle(row -> {
              try {
                return String.format("id: %d, value: %s\n",
                  row.getObject("id", Long.class),
                  row.getObject("value", String.class));
              }
              catch (SQLException sqlException) {
                throw new CompletionException(sqlException);
              }
            });

        return FlowAdapters.toPublisher(rowPublisher);
      }
      catch (SQLException sqlException) {
        return Flux.error(sqlException);
      }
    }
```


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```
  void close(PreparedStatement preparedStatement) {
    try {
      preparedStatement.close();
    }
    catch (SQLException sqlException) {
      throw new RuntimeException(sqlException);
    }
  }

}
```


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27

OCI Connection Pooling

The Java Database Connectivity (JDBC) Oracle Call Interface (OCI) driver connection pooling functionality is part of the JDBC client. This functionality is provided by the `OracleOCIConnectionPool` class.

A JDBC application can have multiple pools at the same time. Multiple pools can correspond to multiple application servers or pools to different data sources. The connection pooling provided by the JDBC OCI driver enables applications to have multiple logical connections, all using a small set of physical connections. Each call on a logical connection gets routed on to the physical connection that is available at the time of call.

This chapter contains the following sections:

- Background of OCI Driver Connection Pooling
- Comparison Between OCI Driver Connection Pooling and Shared Servers
- About Defining an OCI Connection Pool
- About Connecting to an OCI Connection Pool
- Sample Code for OCI Connection Pooling
- Statement Handling and Caching
- JNDI and the OCI Connection Pool

> **Note**
>
> Use OCI connection pooling if you need session multiplexing. Otherwise, Oracle recommends using Universal Connection Pool.

27.1 Background of OCI Driver Connection Pooling

The Oracle JDBC OCI driver provides several transaction monitor capabilities, such as the fine-grained management of Oracle sessions and connections. It is possible for a high-end application server or transaction monitor to multiplex several sessions over fewer physical connections on a call-level basis, thereby achieving a high degree of scalability by pooling of connections and back-end Oracle server processes.

The connection pooling provided by the `OracleOCIConnectionPool` interface simplifies the session/connection separation interface hiding the management of the physical connection pool. The Oracle sessions are the `OracleOCIConnection` objects obtained from `OracleOCIConnectionPool`. The connection pool itself is usually configured with a much smaller shared pool of physical connections, translating to a back-end server pool containing an identical number of dedicated server processes. Note that many more Oracle sessions can be multiplexed over this pool of fewer shared connections and back-end Oracle processes.

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27.2 Comparison Between OCI Driver Connection Pooling and Shared Servers

In some ways, what OCI driver connection pooling offers on the middle tier is similar to what shared server processes offer on the back end. OCI driver connection pooling makes a dedicated server instance behaves as a shared instance by managing the session multiplexing logic on the middle tier. Therefore, the pooling of dedicated server processes and incoming connections into the dedicated server processes is controlled by the OCI connection pool on the middle tier.

The main difference between OCI connection pooling and shared servers is that in the case of shared servers, the connection from the client is typically to a dispatcher in the database instance. The dispatcher is responsible for directing the client request to an appropriate shared server. On the other hand, the physical connection from the OCI connection pool is established directly from the middle tier to the Oracle dedicated server process in the back-end server pool.

Note that OCI connection pool is mainly beneficial only if the middle tier is multithreaded. Each thread could maintain a session to the database. The actual connections to the database are maintained by `OracleOCIConnectionPool`, and these connections, including the pool of dedicated database server processes, are shared among all the threads in the middle tier.

27.3 About Defining an OCI Connection Pool

This section describes the following concepts:

- Overview of Creating an OCI Connection Pool
- Importing the oracle.jdbc.pool and oracle.jdbc.oci Packages
- Creating an OCI Connection Pool
- Setting the OCI Connection Pool Parameters
- Checking the OCI Connection Pool Status

27.3.1 Overview of Creating an OCI Connection Pool

An OCI connection pool is created at the beginning of the application. Creating connections from a pool is quite similar to creating connections using the `OracleDataSource` class.

The `oracle.jdbc.pool.OracleOCIConnectionPool` class, which extends the `OracleDataSource` class, is used to create OCI connection pools. From an `OracleOCIConnectionPool` instance, you can obtain logical connection objects. These connection objects are of the `OracleOCIConnection` class type. This class implements the `OracleConnection` interface. The `Statement` objects you create from the `OracleOCIConnection` instance have the same fields and methods as `OracleStatement` objects you create from `OracleConnection` instances.

The following code shows header information for the `OracleOCIConnectionPool` class:

```
/*
   * @param us  ConnectionPool user-id.
   * @param p   ConnectionPool password
   * @param name  logical name of the pool. This needs to be one in the
   *                   tnsnames.ora configuration file.
```


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```
     @param config (optional)  Properties of the pool, if the default does not
                suffice. Default connection configuration is min =1, max=1,
                incr=0
                  Please refer setPoolConfig for property names.

                 Since this is optional, pass null if the default configuration
                 suffices.

   * @return
   *
   * Notes: Choose a userid and password that can act as proxy for the users
   *        in the getProxyConnection() method.

            If config is null, then the following default values will take
            effect
            CONNPOOL_MIN_LIMIT = 1
            CONNPOOL_MAX_LIMIT = 1
            CONNPOOL_INCREMENT = 0

*/

public synchronized OracleOCIConnectionPool
  (String       user,    String   password,  String name, Properties config)
  throws SQLException

/*
 * This will use the user-id, password and connection pool name values set
   LATER using the methods setUser, setPassword, setConnectionPoolName.

 * @return
 *
 * Notes:

     No OracleOCIConnection objects can be created on
     this class unless the methods setUser, setPassword, setPoolConfig
     are invoked.
     When invoking the setUser, setPassword later, choose a userid and
     password that can act as proxy for the users
 *   in the getProxyConnection() method.
 */
  public synchronized OracleOCIConnectionPool ()
    throws SQLException
```

27.3.2 Importing the oracle.jdbc.pool and oracle.jdbc.oci Packages

Before you create an OCI connection pool, import the following to have Oracle OCI connection pooling functionality:

```
import oracle.jdbc.pool.*;
import oracle.jdbc.oci.*;
```

27.3.3 Creating an OCI Connection Pool

The following code show how you create an instance of the `OracleOCIConnectionPool` class called `cpool`:

```
OracleOCIConnectionPool cpool = new OracleOCIConnectionPool
    ("HR", "hr", "jdbc:oracle:oci:@(description=(address=(host=
    localhost)(protocol=tcp)(port=5221))(connect_data=(INSTANCE_NAME=orcl)))",
    poolConfig);
```


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`poolConfig` is a set of properties that specify the connection pool. If `poolConfig` is null, then the default values are used. For example, consider the following:

- `poolConfig.put (OracleOCIConnectionPool.CONNPOOL_MIN_LIMIT, "4");`
- `poolConfig.put (OracleOCIConnectionPool.CONNPOOL_MAX_LIMIT, "10");`
- `poolConfig.put (OracleOCIConnectionPool.CONNPOOL_INCREMENT, "2");`

As an alternative to the constructor call, you can create an instance of the `OracleOCIConnectionPool` class using individual methods to specify the user, password, and connection string.

```
OracleOCIConnectionPool cpool = new OracleOCIConnectionPool ( );
cpool.setUser("HR");
cpool.setPassword("hr");
cpool.setURL("jdbc:oracle:oci:@(description=(address=(host=
    localhost)(protocol=tcp)(port=5221))(connect_data=(INSTANCE_NAME=orcl)))");
cpool.setPoolConfig(poolConfig);  // In case you want to specify a different
                                  // configuration other than the default
                                  // values.
```

27.3.4 Setting the OCI Connection Pool Parameters

The connection pool configuration is determined by the following `OracleOCIConnectionPool` class attributes:

- `CONNPOOL_MIN_LIMIT`

  Specifies the minimum number of physical connections that can be maintained by the pool.

- `CONNPOOL_MAX_LIMIT`

  Specifies the maximum number of physical connections that can be maintained by the pool.

- `CONNPOOL_INCREMENT`

  Specifies the incremental number of physical connections to be opened when all the existing ones are busy and a call needs one more connection; the increment is done only when the total number of open physical connections is less than the maximum number that can be opened in that pool.

- `CONNPOOL_TIMEOUT`

  Specifies how much time must pass before an idle physical connection is disconnected; this does not affect a logical connection.

- `CONNPOOL_NOWAIT`

  Specifies, if enabled, that an error is returned if a call needs a physical connection while the maximum number of connections in the pool are busy. If disabled, a call waits until a connection is available. Once this attribute is set to `true`, it cannot be reset to `false`.

You can configure all of these attributes dynamically. Therefore, an application has the flexibility of reading the current load, that is number of open connections and number of busy connections, and adjusting these attributes appropriately, using the `setPoolConfig` method.

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> **Note**
>
> The default values for the `CONNPOOL_MIN_LIMIT`, `CONNPOOL_MAX_LIMIT`, and `CONNPOOL_INCREMENT` parameters are `1`, `1`, and `0`, respectively.

The `setPoolConfig` method is used to configure OCI connection pool properties. The following is a typical example of how the `OracleOCIConnectionPool` class attributes can be set:

```
...
java.util.Properties p  = new java.util.Properties( );
p.put (OracleOCIConnectionPool.CONNPOOL_MIN_LIMIT, "1");
p.put (OracleOCIConnectionPool.CONNPOOL_MAX_LIMIT, "5");
p.put (OracleOCIConnectionPool.CONNPOOL_INCREMENT, "2");
p.put (OracleOCIConnectionPool.CONNPOOL_TIMEOUT, "10");
p.put (OracleOCIConnectionPool.CONNPOOL_NOWAIT, "true");
cpool.setPoolConfig(p);
...
```

Observe the following rules when setting these attributes:

- `CONNPOOL_MIN_LIMIT`, `CONNPOOL_MAX_LIMIT`, and `CONNPOOL_INCREMENT` are mandatory.
- `CONNPOOL_MIN_LIMIT` must be a value greater than zero.
- `CONNPOOL_MAX_LIMIT` must be a value greater than or equal to `CONNPOOL_MIN_LIMIT` plus `CONNPOOL_INCREMENT`.
- `CONNPOOL_INCREMENT` must be a value greater than or equal to zero.
- `CONNPOOL_TIMEOUT` must be a value greater than zero.
- `CONNPOOL_NOWAIT` must be `true` or `false`.

> **See Also**
>
> *Oracle Call Interface Programmer's Guide*

27.3.5 Checking the OCI Connection Pool Status

To check the status of the connection pool, use the following methods from the `OracleOCIConnectionPool` class:

- `int getMinLimit()`

  Retrieves the minimum number of physical connections that can be maintained by the pool.

- `int getMaxLimit()`

  Retrieves the maximum number of physical connections that can be maintained by the pool.

- `int getConnectionIncrement()`

  Retrieves the incremental number of physical connections to be opened when all the existing ones are busy and a call needs a connection.

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- `int getTimeout()`

  Retrieves the specified time (in seconds) that a physical connection in a pool can remain idle before it is disconnected; the age of a connection is based on the Least Recently Used (LRU) algorithm.

- `String getNoWait()`

  Retrieves if the `NOWAIT` property is enabled. It returns a string of "`true`" or "`false`".

- `int getPoolSize()`

  Retrieves the number of physical connections that are open. This should be used only as an estimate and for statistical analysis.

- `int getActiveSize()`

  Retrieves the number of physical connections that are open and busy. This should be used only as an estimate and for statistical analysis.

- `boolean isPoolCreated()`

  Retrieves if the pool has been created. The pool is actually created when `OracleOCIConnection(user, password, url, poolConfig)` is called or when `setUser`, `setPassword`, and `setURL` has been done after calling `OracleOCIConnection()`.

27.4 About Connecting to an OCI Connection Pool

The `OracleOCIConnectionPool` class, through a `getConnection` method call, creates an instance of the `OracleOCIConnection` class. This instance represents a connection.

Because the `OracleOCIConnection` class extends `OracleConnection` class, it has the functionality of this class too. Close the `OracleOCIConnection` objects once the user session is over, otherwise, they are closed when the pool instance is closed.

There are two ways of calling `getConnection`:

- `OracleConnection getConnection()`

  If you do not supply the user name and password, then the default user name and password used for the creation of the connection pool are used while creating the connection objects.

- `OracleConnection getConnection(String user, String password)`

  If you this method, you will get a logical connection identified with the specified user name and password, which can be different from that used for pool creation.

The following code shows the signatures of the overloaded `getConnection` method:

```
public synchronized OracleConnection getConnection( )
                    throws SQLException

/*
 * For getting a connection to the database.
 *
 * @param us  Connection user-id
 * @param p   Connection password
 * @return     connection object
 */
public synchronized OracleConnection getConnection(String us, String p)
throws SQLException
```


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As an enhancement to `OracleConnection`, the following new method is added into `OracleOCIConnection` as a way to change the password for the user:

```
void passwordChange (String user, String oldPassword, String newPassword)
```

27.5 Sample Code for OCI Connection Pooling

The following code illustrates the use of OCI connection pooling in a sample application:

```
import java.sql.DriverManager;
import java.sql.Connection;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.Properties;
import oracle.jdbc.OracleDriver;
import oracle.jdbc.pool.OracleOCIConnectionPool;

public class conPoolAppl extends Thread
{
  public static final String query = "SELECT object_name FROM all_objects WHERE rownum <
300";
  static public void main(String args[]) throws SQLException
  {
    int _maxCount = 10;
    Connection []conn = new Connection[_maxCount];
    try
    {
      String s = null;   //System.getProperty ("JDBC_URL");
      String url = "jdbc:oracle:oci8:@localhost";
      OracleOCIConnectionPool cpool = new OracleOCIConnectionPool("HR", "hr", url, null);

      // Print out the default configuration for the OracleOCIConnectionPool
      System.out.println ("-- The default configuration for the OracleOCIConnectionPool
--");
      displayPoolConfig(cpool);

      //Set up the initial pool configuration
      Properties p1  = new Properties();
      p1.put (OracleOCIConnectionPool.CONNPOOL_MIN_LIMIT, Integer.toString(1));
      p1.put (OracleOCIConnectionPool.CONNPOOL_MAX_LIMIT, Integer.toString(_maxCount));
      p1.put (OracleOCIConnectionPool.CONNPOOL_INCREMENT, Integer.toString(1));

      // Enable the initial configuration
      cpool.setPoolConfig(p1);

      Thread []t = new Thread[_maxCount];
      for (int i = 0; i < _maxCount; ++i)
      {
        conn[i] = cpool.getConnection("HR", "hr");
        if ( conn[i] == null )
        {
          System.out.println("Unable to create connection.");
          return;
        }
        t[i] = new conPoolAppl (i, conn[i]);
        t[i].start ();
        //displayPoolConfig(cpool);
      }

      ((conPoolAppl)t[0]).startAllThreads ();
```


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```
    try
    {
      Thread.sleep (200);
    }
    catch (Exception ea) {}

    displayPoolConfig(cpool);
    for (int i = 0; i < _maxCount; ++i)
      t[i].join ();
  }
  catch(Exception ex)
  {
    System.out.println("Error: " + ex);
    ex.printStackTrace ();
    return;
  }
  finally
  {
    for (int i = 0; i < _maxCount; ++i)
      if (conn[i] != null)
      conn[i].close ();
  }
} //end of main

private Connection m_conn;
private static boolean m_startThread = false;
private int m_threadId;

public conPoolAppl (int i, Connection conn)
{
  m_threadId = i;
  m_conn = conn;
}

public void startAllThreads ()
{
  m_startThread = true;
}

public void run ()
{
  while (!m_startThread) Thread.yield ();
  try
  {
    doQuery (m_conn);
  }
  catch (SQLException ea)
  {
    System.out.println ("*** Thread id: " + m_threadId);
    ea.printStackTrace ();
  }
} // end of run

private static void doQuery (Connection conn) throws SQLException
{
  PreparedStatement pstmt = null;
  ResultSet rs = null;
  try
  {
    pstmt = conn.prepareStatement (query);
    rs = pstmt.executeQuery ();
    while (rs.next ())
```


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```
      {
        //System.out.println ("Object name: " +rs.getString (1));
      }
    }
    catch (Exception ea)
    {
      System.out.println ("Error during execution: " +ea);
      ea.printStackTrace ();
    }
    finally
    {
      if (rs != null)
        rs.close ();
      if (pstmt != null)
        pstmt.close ();
      if (conn != null)
        conn.close ();
    }
  }  // end of doQuery (Connection)

  // Display the current status of the OracleOCIConnectionPool
  private static void displayPoolConfig (OracleOCIConnectionPool cpool) throws
SQLException
  {
    System.out.println (" Min poolsize Limit: " + cpool.getMinLimit());
    System.out.println (" Max poolsize Limit: " + cpool.getMaxLimit());
  /*
    System.out.println (" Connection Increment: " + cpool.getConnectionIncrement());
    System.out.println (" NoWait: " + cpool.getNoWait());
    System.out.println (" Timeout: " + cpool.getTimeout());
  */
    System.out.println (" PoolSize: " + cpool.getPoolSize());
    System.out.println (" ActiveSize: " + cpool.getActiveSize());
  }

}  // end of class conPoolAppl
```

27.6 Statement Handling and Caching

Statement caching is supported with `OracleOCIConnectionPool`. The caching improves performance by not having to open, parse, and close cursors. When `OracleOCIConnection.prepareStatement` ("*a_SQL_query*") is processed, the statement cache is searched for a statement that matches the SQL query. If a match is found, then you can reuse the `Statement` object instead of incurring the cost of creating another `Statement` object. The cache size can be dynamically increased or decreased. The default cache size is zero.

> **Note**
>
> The `OracleStatement` object created from `OracleOCIConnection` has the same behavior as one that is created from `OracleConnection`.

27.7 JNDI and the OCI Connection Pool

The Java Naming and Directory Interface (JNDI) feature makes the properties of a Java object persist, therefore these properties can be used to construct a new instance of the object, such as cloning the object. The benefit is that the old object can be freed, and at a later time a new

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object with exactly the same properties can be created. The `InitialContext.bind` method makes the properties persist, either on file or in a database, while the `InitialContext.lookup` method retrieves the properties from the persistent store and creates a new object with these properties.

`OracleOCIConnectionPool` objects can be bound and looked up using the JNDI feature. No new interface calls in `OracleOCIConnectionPool` are necessary.

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28

Database Resident Connection Pooling

Database Resident Connection Pool (DRCP) is a connection pool in the server, which many clients can share. You should use DRCP when the number of active connections, at a given point of time, is reasonably less than the number of open connections. DRCP is particularly useful for applications with a large number of middle-tier servers. The Database Resident Connection Pooling feature increases Database server scalability and resolves the resource wastage issues of middle-tier connection pooling.

This chapter contains the following sections:

- Overview of Database Resident Connection Pooling
- Enabling Database Resident Connection Pooling
- Pooled Server Processes Across Multiple Connection Pools
- Multi-Pool Support in DRCP
- Tagging Support in Database Resident Connection Pooling
- APIs for Using Database Resident Connection Pooling

28.1 Overview of Database Resident Connection Pooling

In middle-tier connection pools, every connection pool maintains a minimum number of open connections to the server. Each open connection represents resources that are in use at the server. However, your application does not use all the open connections at a given point of time, which means that there are unused resources that consume server resources unnecessarily. In a multiple middle-tier scenario, every middle tier maintains an individual connection pool, without sharing connections with other middle-tier connection pools, and retains the open connections for long, even if some of those are inactive. For an application with a large number of middle-tier connection pools, the number of inactive connections to the Database server is significantly large in such case, which wastes a lot of Database resources.

For example, if in your application, the minimum pool size is 200 for every middle-tier connection pool, the connection pool has 200 open connections to the server, and the Database server has 200 server processes associated with these connections. If you have 30 similar middle-tier connection pools in your application, then the server has 6000 (200 * 30) corresponding server processes running at any given point of time. Typically, on an average only 5% of the connections, and in turn, server processes are in use simultaneously. So, out of the 6,000 server processes, only 300 server processes are active at any given time. This leads to 5,700 unused processes on the server, resulting in wasted resources on the server.

The Database Resident Connection Pool implementation creates a pool on the Database server side, which is shared across multiple client pools. This significantly lowers memory consumption on the Database server because of reduced number of server processes running simultaneously and increases its scalability.

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> **See Also**
>
> - *Oracle AI Database Concepts*
> - *Oracle AI Database Administrator's Guide*

28.2 Enabling Database Resident Connection Pooling

This section describes how to enable Database Resident Connection Pooling (DRCP) on the server side and the client side:

- Enabling DRCP on the Server Side
- Enabling DRCP on the Client Side

28.2.1 Enabling DRCP on the Server Side

You must be a database administrator (DBA) and must log on as `SYSDBA` to start and end a Database Resident Connection Pool (DRCP). This section discusses the following related concepts:

- Starting a Database Resident Connection Pool
- Configuring a Database Resident Connection Pool
- Ending a Database Resident Connection Pool
- Setting the Statement Cache Size

> **Note**
>
> You can leverage the DRCP features only with a connection pool on the client because JDBC does not have a default pool on its own.

Starting a Database Resident Connection Pool

Run the `start_pool` method in the `DBMS_CONNECTION_POOL` package with the default settings to start the default Oracle Database resident connection pool, namely, `SYS_DEFAULT_CONNECTION_POOL`. For example:

```
sqlplus /nolog
connect / as sysdba
execute dbms_connection_pool.start_pool();
```

Configuring a Database Resident Connection Pool

Use the procedures in the `DBMS_CONNECTION_POOL` package to configure the default Oracle Database resident connection pool. By default, this connection pool uses default parameter values.

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> **See Also**
>
> - DBMS_CONNECTION_POOL
> - Configuring Database Resident Connection Pooling

Ending a Database Resident Connection Pool

Run the `stop_pool` method in the `DBMS_CONNECTION_POOL` package to end the pool. For example:

```
sqlplus /nolog
connect / as sysdba
execute dbms_connection_pool.stop_pool();
```

Setting the Statement Cache Size

If you use DRCP, then the server caches statement information on the server side. So, you must specify the statement cache size on the server side in the following way, where 50 is the preferred size:

```
execute DBMS_CONNECTION_POOL.CONFIGURE_POOL (session_cached_cursors=>50);
```

Related Topics

- About Statement Caching

28.2.2 Enabling DRCP on the Client Side

Perform the following steps to enable DRCP on the client side:

> **Note**
>
> The example in this section uses Universal Connection Pool (UCP) as the client-side connection pool. For any other connection pool, you must use `oracle.jdbc.pool.OracleConnectionPoolDataSource` as the connection factory.

- Pass a non-null and non-empty `String` value to the `oracle.jdbc.DRCPConnectionClass` connection property
- Append (`SERVER=POOLED`) to the `CONNECT_DATA` configuration parameter in the long connection string

You can also specify (`<service_name>=POOLED`) in the short connection string in the following way:

```
jdbc:oracle:thin:@<host>:<port>/<service_name>[:POOLED]
```

For example:

```
jdbc:oracle:thin:@localhost:5221/orcl:POOLED
```

The following code snippet shows how to enable DRCP on the client side:

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> **Note**
>
> In UCP, if you do not provide a connection class, then the connection pool name is used as the connection class name by default.

Example 28-1 Enabling DRCP on Client Side Using Universal Connection Pool

```
String url = "jdbc:oracle:thin:@localhost:5521/orcl:POOLED";
PoolDataSource pds = PoolDataSourceFactory.getPoolDataSource();
pds.setConnectionFactoryClassName("oracle.jdbc.pool.OracleDataSource");
// Set DataSource Property
pds.setUser("HR");
pds.setPassword("hr");
System.out.println ("Connecting to " + url);
pds.setURL(url);
pds.setConnectionPoolName("HR-Pool1");
pds.setMinPoolSize(2);
pds.setMaxPoolSize(3);
pds.setInitialPoolSize(2);
Properties prop = new Properties();
prop.put("oracle.jdbc.DRCPConnectionClass", "HR-Pool1");
pds.setConnectionProperties(prop);
```

28.3 Pooled Server Processes Across Multiple Connection Pools

You can set the same Database Resident Connection Pool (DRCP) connection class name for all the pooled server processes on the server and share those across multiple connection pools on the server. For setting the DRCP connection class name, use the `oracle.jdbc.DRCPConnectionClass` connection property.

28.4 Multi-Pool Support in DRCP

You can now develop applications that use multiple, named DRCP pools. This helps in avoiding situations, where connections from a few services can occupy all the pooled servers of DRCP, while the rest of the connections from the other services may need to wait for the availability of the pooled servers.

For making DRCP mark the connection against the appropriate pool, specify `(POOL_NAME=<pool_name>)` in the connection string, along with `(SERVER=POOLED)`, as shown in the following example:

```
(DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)(HOST=<host>)(PORT=<port>))
(CONNECT_DATA=(SERVER=POOLED)(POOL_NAME=<pool_name>)))
```

It is not mandatory to create a DRCP pool for all the services, a few services may have multi-pool DRCP and the rest of the services may share the per-PDB or CDB-wide DRCP. If you are a PDB administrator, then by connecting to a PDB, you can also perform administrative operations like creating and destroying the DRCP.

The following procedures have been added to the `DBMS_CONNECTION_POOL` package to add and remove pooled servers from the multi-pool DRCP:

ADD_POOL Procedure

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This procedure adds a new pool to the multi-pool DRCP. For example:

```
exec dbms_connection_pool.add_pool('mypool')
```

REMOVE_POOL Procedure

This procedure removes a new pool from the multi-pool DRCP. For example:

```
exec dbms_connection_pool.remove_pool('mypool')
```

See Also

- *Oracle Database Development Guide*
- *Oracle Database PL/SQL Packages and Types Reference*

28.5 Tagging Support in Database Resident Connection Pooling

Database Resident Connection Pooling (DRCP) provides an option to associate a server process with a particular tag name. You can apply a tag to a given connection and retrieve that tagged connection later. Connection tagging enhances session pooling because you can retrieve specific sessions easily.

DRCP also provides support for multiple tagging, which is disabled by default. Set the `oracle.jdbc.UseDRCPMultipletag` connection property to `TRUE` for enabling this feature in your DRCP application.

Once you enable the multiple tagging feature, you can use the same APIs for setting single or multiple DRCP tags. The only difference between both the cases is the separator. You must separate the key and the value of a DRCP tag by an equal (=) character, whereas, you must separate multiple tags from one another by a semi-colon (;) character.

Remember the following points while working with DRCP tags:

- You cannot specify the key or the value of a tag as null or empty.
- When you specify multiple tags, then the leftmost tag has the highest priority and the rightmost tag has the lowest priority.
- While retrieving a tagged connection, if a complete match is not found (all tags are not matched), then it searches for a partial match.
- You cannot set the `RESET_STATE` service attribute to `LEVEL1` or `LEVEL2`.

See Also

Oracle Call Interface Programmer's Guide for more information about session pooling and connection tagging

28.6 PL/SQL Callback for Session State Fix Up

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Starting from Oracle Database 12*c* Release 2 (12.2.0.1), a PL/SQL based fix-up callback for the session state can be provided on the server. This application-provided callback transforms a session checked out from the pool to the desired state requested by the application. This callback works with or without Database Resident Connection Pooling (DRCP).

> **Note**
>
> The PL/SQL based fix-up callback is only applicable for multiple tagging.

Using this callback can improve the performance of your application because the fix-up logic is run for the session state on the server. So, this feature eliminates application round-trips to the database for the fix-up logic. An appropriate installation user, who must be granted execute permissions on the related package, should register the fix-up callback during application installation.

Example 28-2 Example of PL/SQL Fix-Up Callback

Following is an example implementation of the PL/SQL fix up callback to fix up the session properties `SCHEMA` and `CURRENCY`:

```
CREATE OR REPLACE PACKAGE mycb_pack AS
PROCEDURE mycallback (
desired_props IN VARCHAR2,
actual_props IN VARCHAR2
);
END;
/

CREATE OR REPLACE PACKAGE BODY mycb_pack AS
PROCEDURE mycallback (
desired_props IN VARCHAR2,
actual_props IN VARCHAR2
) IS
property VARCHAR2(64);
key VARCHAR2(64);
value VARCHAR2(64);
pos number;
pos2 number;
pos3 number;
idx1 number;

BEGIN
idx1:=1;

pos:=1;
pos2:=1;
pos3:=1;
property := 'tmp';
-- To check if desired properties are part of actual properties
while (pos > 0 and length(desired_props)>pos)
loop
pos := instr (desired_props, ';', 1, idx1);
if (pos=0)
then
```


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```
property := substr (desired_props, pos2);
else
property := substr (desired_props, pos2, pos-pos2);
end if ;
pos2 := pos+1;
pos3 := instr (property, '=', 1, 1);
key := substr (property, 1, pos3-1);
value := substr (property, pos3+1);
if (key = 'CURRENCY') then
EXECUTE IMMEDIATE 'ALTER SESSION SET NLS_CURRENCY=''' || value || '''';
elsif (key = 'SCHEMA') then
EXECUTE IMMEDIATE 'ALTER SESSION SET CURRENT_SCHEMA=' || value;
end if;
idx1 := idx1+1;
end loop;

END; -- mycallback
END mycb_pack;
/
```

See Also

Oracle AI Database JDBC Java API Reference

28.7 APIs for Using Database Resident Connection Pooling

If you want to take advantage of Database Resident Connection Pooling (DRCP) with higher granular control for your custom connection pool implementations, then you must use the following APIs declared in the `oracle.jdbc.OracleConnection` interfaces:

- `attachServerConnection`
- `detachServerConnection`
- `isDRCPEnabled`
- `isDRCPMultitagEnabled`
- `getDRCPReturnTag`
- `needToPurgeStatementCache`
- `getDRCPState`

See Also

Oracle Database JDBC Java API Reference

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29

JDBC Support for Database Sharding

This section describes Oracle JDBC support for the Database Sharding feature.

- Overview of Database Sharding for JDBC Users
- Creating JDBC Connections Using a Sharding Key
- Overview of the Sharding Data Source
- Benefits of the Sharding Data Source
- Limitations of the Sharding Data Source

29.1 Overview of Database Sharding for JDBC Users

Modern web applications face new scalability challenges with huge volumes of data. A commonly accepted solution to this problem is sharding. *Sharding* is a data tier architecture, where data is horizontally partitioned across independent databases. Each database in such a configuration is called a *shard*.

All shards together make up a single logical database, which is referred to as a Globally Distributed Database. Sharding is a *shared-nothing* database architecture because shards do not share physical resources such as CPU, memory, or storage devices.

Sharding uses Global Data Services (GDS), where GDS routes a client request to an appropriate database based on parameters such as availability, load, network latency, and replication lag. A GDS pool is a set of replicated databases that offer the same global service. The databases in a GDS pool can be located in multiple data centers across different regions. A sharded GDS pool contains all shards of an Oracle Globally Distributed Database and their replicas, and appears as a single Globally Distributed Database to the database clients.

Starting from Oracle Database 12*c* Release 2 (12.2.0.1), Oracle JDBC supports database sharding. The JDBC driver recognizes the specified sharding key and super sharding key and connects to the relevant shard that contains the data. Once the connection is established to a shard, then any database operations, such as DMLs, SQL queries and so on, are supported and executed in the usual way.

See Also

- *Oracle Globally Distributed Database*
- *Universal Connection Pool Developer's Guide*
- The OracleShardingKey Interface
- The OracleShardingKeyBuilder Interface
- The OracleConnectionBuilder Interface

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29.2 Creating JDBC Connections Using a Sharding Key

The shard-aware applications must identify and build the sharding key and the super sharding key, which are required to establish a connection to an Oracle Globally Distributed Database.

Example 29-1 Building a Sharding Key

The following example shows how to build a sharding key:

```
import java.sql.Connection;
import java.sql.JDBCType;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.ShardingKey;
import java.sql.Statement;

import oracle.jdbc.pool.OracleDataSource;

public class JDBCShardingExample {

    public static void main(String[] args) throws Exception {

        OracleDataSource ods = new OracleDataSource();
        ods.setURL("jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(HOST=myhost)
(PORT=<gsm-listener-port>)
            (PROTOCOL = tcp))(CONNECT_DATA = (SERVICE_NAME = gsmservicename)))
    ");
    ods.setUser(<db_user_name>);
    ods.setPassword(<db_password>);

    int empId = 1234;
    String location = "US";

    // Employee ID is the sharding key column
    ShardingKey shardingKey = ods.createShardingKeyBuilder()
        .subkey(empId, JDBCType.INTEGER)
        .build();

    // Employee location is the super sharding key column
    ShardingKey superShardingKey = ods.createShardingKeyBuilder()
        .subkey(location, JDBCType.VARCHAR)
        .build();

    // Get a direct connection to the shard that contains the record of the
employee
    // with employee id = 1234 and location="US", using sharding key and
super sharding key

    try (Connection connection = ods.createConnectionBuilder()
        .shardingKey(shardingKey)
        .superShardingKey(superShardingKey)
        .build()) {

              PreparedStatement pst = connection.prepareStatement("select *
from employee where emp_id=? and location=?");
```


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```
                pst.setInt(1, 1234);
                pst.setString(2, "US");
                ResultSet rs = pst.executeQuery();
                // Retrieve the employee details using resultset
                rs.close();
                pst.close();
            }
        }

}
```

Note

- There is a fixed set of data types that are valid and supported. If any unsupported data types are used as keys, then exceptions are thrown. The following list specifies the supported data types:
  - `OracleType.VARCHAR2/JDBCType.VARCHAR`
  - `OracleType.CHAR/JDBCType.CHAR`
  - `OracleType.NVARCHAR/JDBCType.NVARCHAR`
  - `OracleType.NCHAR/JDBCType.NCHAR`
  - `OracleType.NUMBER/JDBCType.NUMERIC`
  - `OracleType.FLOAT/ JDBCType.FLOAT`
  - `OracleType.DATE/ JDBCType.DATE`
  - `OracleType.TIMESTAMP/JDBCType.TIMESTAMP`
  - `OracleType.TIMESTAMP_WITH_LOCAL_TIME_ZONE`
  - `OracleType.RAW`
- You must provide a sharding key that is compliant to the NLS formatting specified in the database.

29.3 Overview of the Sharding Data Source

Since Oracle Database Release 21c, the JDBC Thin driver can establish Java connectivity to an Oracle Globally Distributed Database without the need to furnish a sharding key. In this case, you do not need to identify and build the sharding key and the super sharding key to establish a connection.

The `oracle.jdbc.pool.OracleDataSource`, with sharding capability, scales out transparently to an Oracle Globally Distributed Database as it does not involve any change to the application code. When the sharding key can be derived from SQL or PL/SQL, the JDBC driver can identify it without the need for the application to send the sharding key.

For achieving this capability, you must set the connection property `OracleConnection.CONNECTION_PROPERTY_USE_SHARDING_DRIVER_CONNECTION` to `true`. The default value of this connection property is `false`.

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29.3.1 Example: How to Use the Sharding Data Source

The example in this section shows how to use the sharding data source.

Example 29-2 Using the Sharding Data Source

```
import java.sql.Connection;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.ArrayList;
import java.util.Iterator;
import java.util.List;
import java.util.Properties;

import javax.sql.DataSource;

import oracle.jdbc.internal.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;

public class ShardingDataSourceSample {
      public static void main(String[] args) throws SQLException {
            ShardingDataSourceSample sample = new ShardingDataSourceSample();
            DataSource ds = sample.getDataSource();
            // get the details of following customers
            int[] customerIds = new int[] { 100, 101, 102, 103, 104, 105 };
            try (Connection conn = ds.getConnection()) {
                  for (int id : customerIds) {
                        sample.displayCustomerDetails(conn, id);
                  }
                  System.out.println(((OracleConnection)
conn).getPercentageQueryExecutionOnDirectShard());
            }
      }

      private void displayCustomerDetails(Connection conn, int id) throws
SQLException {
            try (PreparedStatement pstmt = conn.prepareStatement("SELECT *
FROM CUSTOMER where ID = ?")) {
                  pstmt.setInt(1, id);
                  try (ResultSet rs = pstmt.executeQuery()) {
                        while (rs.next()) {
                              // print the customer details
                        }
                  }
            }
      }

      private DataSource getDataSource() throws SQLException {
        OracleDataSource ds = new OracleDataSource();
    ds.setURL(<gsmURL>);
    ds.setUser(<userName>);
    ds.setPassword(<password>);
    Properties prop = new Properties();
    // Connection property to enable sharding data source feature
```


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```
prop.setProperty(OracleConnection.CONNECTION_PROPERTY_USE_SHARDING_DRIVER_CONN
ECTION, "true");
    ds.setConnectionProperties(prop);
    return ds;
  }
}
```

29.4 Benefits of the Sharding Data Source

Following are the benefits of the new sharding data source:

- You do not need to use the sharding APIs to pass the sharding key because the sharding data source derives the sharding key from the SQL statement.
- You do not need to configure the Universal Connection Pool (UCP) because the sharding data source uses the auto tune feature of UCP.
- You do not need to check-in or check-out a physical connection for every new sharding key because the sharding data source does it automatically.
- You do not need to separate cross-shard statements from single-shard statements and create separate connection pools for them because the sharding data source maintains those connections pools.
- The sharding data source enables the prepared statement caching and routes the connection to the direct shard based on the key used in the SQL statement.
- The sharding data source simplifies applications and optimizes application performance without any code change.

29.5 Limitations of the Sharding Data Source

This section describes the limitations of the sharding data source.

- The sharding data source supports only the JDBC Thin driver. It does not support the JDBC OCI driver or the KPRB driver.
- The sharding data source does not support some Oracle JDBC extension APIs such as Direct Path Load, JDBC Dynamic Monitoring Service (DMS) metrics, and so on.
- The sharding data source supports PL/SQL execution only through the catalog database.
- When `AUTO COMMIT` is set to `OFF`, then the execution always happens on the catalog database.
- If the data source property `singleShardTransactionSupport` is set to `TRUE`, then the sharding data source supports local transactions against a single shard, when `AUTO COMMIT` is set to `OFF`.
  The following code snippet shows how to set the `singleShardTransactionSupport` property:

Example 29-3 Single Shard Transaction Support

```
import java.sql.Connection;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.Properties;
```


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```
import javax.sql.DataSource;
import oracle.jdbc.internal.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;

public class SingleShardTransaction {
       public static void main(String[] args) throws SQLException {
              SingleShardTransaction sample = new SingleShardTransaction();
              DataSource ds = sample.getDataSource();
              // Insert and update the details of following customers in a
single transaction
              int[] customerIds = new int[] { 100, 101, 102, 103, 104, 105 };

              try (Connection conn = ds.getConnection()) {
                     conn.setAutoCommit(false);
                     for (int id : customerIds) {
                            sample.insertCustomerDetails(conn, id);
                            sample.displayCustomerDetails(conn, id);
                            sample.updateCustomerDetails(conn, id);
                            sample.displayCustomerDetails(conn, id);
                            conn.commit();
                     }

                     System.out.println(((OracleConnection)
conn).getPercentageQueryExecutionOnDirectShard());
              }
       }

       private void insertCustomerDetails(Connection conn, int id) throws
SQLException {
              String sql = "insert into CUSTOMER values(?, ?, ?, ?)";

              try (PreparedStatement ps = conn.prepareStatement(sql)) {
                     ps.setInt(1, id);
                     ps.setString(2, name);
                     ps.setString(3, email);
                     ps.setString(4, phoneNumber);
                     ps.executeUpdate();
              }
       }

       private void updateCustomerDetails(Connection conn, int id) throws
SQLException {
              String sql = "UPDATE CUSTOMER SET name = ?, email = ?,
phoneNumber = ? WHERE customerId = ?";

              try (PreparedStatement ps = conn.prepareStatement(sql)) {
                     ps.setString(1, name);
                     ps.setString(2, email);
                     ps.setString(3, phoneNumber);
                     ps.setInt(4, id);
                     ps.executeUpdate();
              }
       }

       private void displayCustomerDetails(Connection conn, int id) throws
SQLException {
```


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```
            try (PreparedStatement pstmt = conn.prepareStatement("SELECT *
FROM CUSTOMER where ID = ?")) {
                  pstmt.setInt(1, id);

                  try (ResultSet rs = pstmt.executeQuery()) {
                        while (rs.next()) {
                              // Print the customer details
                        }
                  }
            }
      }

      private DataSource getDataSource() throws SQLException  {
         OracleDataSource ds = new OracleDataSource();
         ds.setURL(<gsmURL>);
         ds.setUser(<userName>);
         ds.setPassword(<password>);
         Properties prop = new Properties();
         // Connection property to enable sharding data source feature

prop.setProperty(OracleConnection.CONNECTION_PROPERTY_USE_SHARDING_DRIVER_CONN
ECTION, "true");

         // Connection property to enable single shard transaction support.
If this property is not set,
         // by default all the transactions are started on catalog DB. When
setting this property value
         // to "true", applications must ensure that all the transactions
span over a single shard only.


prop.setProperty(oracle.jdbc.OracleConnection.CONNECTION_PROPERTY_ALLOW_SINGLE
_SHARD_TRANSACTION_SUPPORT, "true");
         ds.setConnectionProperties(prop);
         return ds;
  }
}
```


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30

Oracle Advanced Queuing

Oracle Advanced Queuing (AQ) provides database-integrated message queuing functionality, which is built on top of Oracle Streams.

It optimizes the functions of Oracle Database, so that messages can be stored persistently, propagated between queues on different computers and databases, and transmitted using Oracle Net Services, HTTP, and HTTPS. Oracle AQ is implemented in database tables, so all operational benefits of high availability, scalability, and reliability are also applicable to queue data. This chapter provides information about the Java interface to Oracle AQ.

> **Note**
>
> - Oracle Advanced Queuing (AQ) is a feature of the Oracle JDBC Thin driver and is not supported by JDBC OCI driver.
> - In Oracle Database 21c Release, support for JSON queues was added. Till Oracle Database 19c Release, supported payload types were `RAW`, `ADT`, `ANYDATA` and `XMLType`. In Oracle Database 23ai, you can also use JSON payload type with array enqueue and dequeue operations.

> **See Also**
>
> *Oracle AI Database Transactional Event Queues and Advanced Queuing User's Guide*

This chapter covers the following topics:

- Functionality and Framework of Oracle Advanced Queuing
- Making Changes to the Database
- AQ Asynchronous Event Notification
- About Creating Messages
- Enqueuing Messages
- Dequeuing Messages
- Examples: Enqueuing and Dequeuing

30.1 Functionality and Framework of Oracle Advanced Queuing

The Oracle JDBC package `oracle.jdbc.aq` provides a fast Java interface to AQ. This package contains the following:

- Classes
  - `AQDequeueOptions`

    Specifies the options available for the dequeue operation

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  - `AQEnqueueOptions`

    Specifies the options available for the enqueue operation

  - `AQFactory`

    Is a factory class for AQ

  - `AQNotificationEvent`

    Is created whenever a new message is enqueued in a queue for which you have registered your interest

- Interfaces
  - `AQAgent`

    Used to represent and identify a user of the queue or a producer or consumer of the message

  - `AQMessage`

    Represents a message that is enqueued or dequeued

  - `AQMessageProperties`

    Contains message properties such as Correlation, Sender, Delay and Expiration, Recipients, and Priority and Ordering

  - `AQNotificationListener`

    Is a listener interface for receiving AQ notification events

  - `AQNotificationRegistration`

    Represents your interest in being notified when a new message is enqueued in a particular queue

These classes and interfaces enable you to access an existing queue, create messages, and enqueue and dequeue messages.

> **Note**
>
> Oracle JDBC drivers do *not* provide any API to create a queue. Queues must be created through the `DBMS_AQADM` PL/SQL package.

> **See Also**
>
> For more information about the APIs, refer to *Oracle Database JDBC Java API Reference*.

30.2 Making Changes to the Database

The code snippets used in this chapter assume that user `HR` is connecting to the database. Therefore, in the database, you must grant the following privileges to `HR`:

```
GRANT EXECUTE ON DBMS_AQ to HR;
GRANT EXECUTE ON DBMS_AQADM to HR;
GRANT AQ_ADMINISTRATOR_ROLE TO HR;
GRANT ADMINISTER DATABASE TRIGGER TO HR;
```


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Before you start enqueuing and dequeuing messages, you must have queues in the Database. For this, you must perform the following:

1. Create a queue table in the following way:

```
BEGIN
    DBMS_AQADM.CREATE_QUEUE_TABLE(
            QUEUE_TABLE =>'HR.RAW_SINGLE_QUEUE_TABLE',
            QUEUE_PAYLOAD_TYPE =>'RAW',
            COMPATIBLE => '10.0');
END;
```

2. Create a queue in the following way:

```
BEGIN
    DBMS_AQADM.CREATE_QUEUE(
            QUEUE_NAME =>'HR.RAW_SINGLE_QUEUE',
            QUEUE_TABLE =>'HR.RAW_SINGLE_QUEUE_TABLE',
END;
```

3. Start the queue in the following way:

```
BEGIN
    DBMS_AQADM.START_QUEUE(
 'HR.RAW_SINGLE_QUEUE',
END;
```

It is a good practice to stop the queue and remove the queue tables from the database. You can perform this in the following way:

1. Stop the queue in the following way:

```
BEGIN
    DBMS_AQADM.STOP_QUEUE(
 HR.RAW_SINGLE_QUEUE',
END;
```

2. Remove the queue tables from the database in the following way:

```
BEGIN
    DBMS_AQADM.DROP_QUEUE_TABLE(
            QUEUE_TABLE =>'HR.RAW_SINGLE_QUEUE_TABLE',
            FORCE => TRUE
END;
```

30.3 AQ Asynchronous Event Notification

A JDBC application can do the following:

- Register to the AQ namespace and receive notification when an enqueue occurs. This can be performed in the following way:

```
 public AQNotificationRegistration registerForAQEvents(
    OracleConnection conn,
    String queueName) throws SQLException
  {
    Properties globalOptions = new Properties();
    String[] queueNameArr = new String[1];
    queueNameArr[0] = queueName;
    Properties[] opt = new Properties[1];
    opt[0] = new Properties();
    opt[0].setProperty(OracleConnection.NTF_AQ_PAYLOAD,"true");
    AQNotificationRegistration[] regArr =
conn.registerAQNotification(queueNameArr,opt,globalOptions);
```


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```
    AQNotificationRegistration reg = regArr[0];
    return reg;
  }
```

- Register subscriptions to database events and receive notifications when the events are triggered

  Registered clients are notified asynchronously when events are triggered or on an explicit AQ enqueue (or a new message is enqueued in a queue for which you have registered your interest). Clients do not need to be connected to a database.

  The following code snippet shows how to subscribe to database events and receive notifications when the events are triggered:

```
class DemoAQRawQueueListener implements AQNotificationListener
{
  OracleConnection conn;
  String queueName;
  String typeName;
  int eventsCount = 0;

  public DemoAQRawQueueListener(String _queueName, String _typeName)
   throws SQLException
  {
   queueName = _queueName;
   typeName = _typeName;
   conn = (OracleConnection)DriverManager.getConnection
     (DemoAQRawQueue.URL, DemoAQRawQueue.USERNAME, DemoAQRawQueue.PASSWORD);
  }

  public void onAQNotification(AQNotificationEvent e)
  {
    try
    {
     AQDequeueOptions deqopt = new AQDequeueOptions();
     deqopt.setRetrieveMessageId(true);
     if(e.getConsumerName() != null)
       deqopt.setConsumerName(e.getConsumerName());
     if((e.getMessageProperties()).getDeliveryMode()
        == AQMessageProperties.DeliveryMode.BUFFERED)
     {
       deqopt.setDeliveryMode(AQDequeueOptions.DEQUEUE_BUFFERED);
       deqopt.setVisibility(AQDequeueOptions.DEQUEUE_IMMEDIATE);
     }
     AQMessage msg = conn.dequeue(queueName,deqopt,typeName);
     byte[] msgId = msg.getMessageId();
     if(msgId != null)
     {
       String mesgIdStr = DemoAQRawQueue.byteBufferToHexString(msgId,20);
       System.out.println("ID of message dequeued = "+mesgIdStr);
     }
     System.out.println(msg.getMessageProperties().toString());
     byte[] payload = msg.getPayload();
     if(typeName.equals("RAW"))
     {
       String payloadStr = new String(payload,0,10);
       System.out.println("payload.length="+payload.length+", value="+payloadStr);
     }
    }
    catch(SQLException sqlex)
    {
     System.out.println(sqlex.getMessage());
    }
```


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```
    eventsCount++;
  }
  public int getEventsCount()
  {
    return eventsCount;
  }
  public void closeConnection() throws SQLException
  {
    conn.close();
  }
}
```

- Register to the listener in the following way:

```
AQNotificationRegistration reg = registerForAQEvents(conn,queueName+":BLUE");
DemoAQRawQueueListener demo_li = new DemoAQRawQueueListener(queueName,queueType);
reg.addListener(demo_li);
```

30.4 About Creating Messages

This section describes the following concepts:

- Creating Messages
- AQ Message Properties
- AQ Message Payload

30.4.1 Creating Messages

Before you enqueue a message, you must create the message. An instance of a class implementing the `AQMessage` interface represents an AQ message. An AQ message contains properties (metadata) and a payload (data). Perform the following to create an AQ message:

1. Create an instance of `AQMessageProperties` in the following way:

```
AQMessageProperties msgprop = AQFactory.createAQMessageProperties();
```

2. Set the property attributes in the following way:

```
msgprop.setCorrelation("mycorrelation");
msgprop.setExceptionQueue("MY_EXCEPTION_QUEUE");
msgprop.setExpiration(0);
msgprop.setPriority(1);
```

3. Create the AQ message using the `AQMessageProperties` object in the following way:

```
AQMessage mesg = AQFactory.createAQMessage(msgprop);
```

4. Set the payload in the following way:

```
byte[] rawPayload = "Example_Payload".getBytes();
mesg.setPayload(new oracle.sql.RAW(rawPayload));
```

30.4.2 AQ Message Properties

The properties of the AQ message are represented by an instance of the `AQMessageProperties` interface. You can set or get the following message properties:

- Dequeue Attempts Count: Specifies the number of attempts that have been made to dequeue the message. This property cannot be set.

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- Correlation: Is an identifier supplied by the producer of the message at the time of enqueuing the message.
- Delay: Is the number of seconds for which the message is in the `WAITING` state. After the specified delay, the message is in the `READY` state and available for dequeuing. Dequeuing a message by using the message ID (msgid) overrides the delay specification.

> **Note**
>
> Delay is not supported with buffered messaging.

- Delivery Mode: Specifies whether the message is a buffered message or a persistent message. This property cannot be set.
- Enqueue Time: Specifies the time at which the message was enqueued. This value is determined by the system and cannot be set by the user.
- Exception Queue: Specifies the name of the queue into which the message is moved if it cannot be processed successfully. Messages are moved in two cases:
  - The number of unsuccessful dequeue attempts has exceeded `max_retries`.
  - The message has expired.
- Expiration: Is the number of seconds during which the message is available for dequeuing, starting from when the message reaches the `READY` state. If the message is not dequeued before it expires, then it is moved to the exception queue in the `EXPIRED` state.
- Message State: Specifies the state of the message at the time of dequeuing the message. This property cannot be set.
- Previous Queue Message ID: Is the ID of the message in the last queue that generated the current message. When a message is propagated from one queue to another, this attribute identifies the ID of the queue from which it was last propagated. This property cannot be set.
- Priority: Specifies the priority of the message. It can be any integer including negative integers; the smaller the value, the higher the priority.
- Recipient list: Is a list of `AQAgent` objects that represent the recipients. The default recipients are the queue subscribers. This parameter is valid only for multiple-consumer queues.
- Sender: Is an identifier specified by the producer at the time of enqueuing the message. It is an instance of `AQAgent`.
- Transaction group: Specifies the transaction group of the message for transaction-grouped queues. It is set after a successful call to the `dequeueArray` method.

30.4.3 AQ Message Payload

Depending on the type of the queue, the payload of the AQ message can be specified using the `setPayload` method of the `AQMessage` interface. The following code snippet illustrates how to set the payload:

```
...
byte[] rawPayload = "Example_Payload".getBytes();
mesg.setPayload(new oracle.sql.RAW(rawPayload));
...
```


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You can retrieve the payload of an AQ message using the `getPayload` method or the appropriate `get`*`XXX`*`Payload` method in the following way:

```
byte[] payload = mesg.getPayload();
```

These methods are defined in the `AQMessage` interface.

30.5 Example: Creating a Message and Setting a Payload

This section provides an example that illustrates how to create a message and set a payload.

Example 30-1 Creating a Message and Setting a Payload

This example shows how to Create an instance of `AQMessageProperties`, set the property attributes, create the AQ message, and set the payload.

```
 AQMessageProperties msgprop = AQFactory.createAQMessageProperties();
    msgprop.setCorrelation("mycorrelation");
    msgprop.setExceptionQueue("MY_EXCEPTION_QUEUE");
    AQAgent ag = AQFactory.createAQAgent();
    ag.setName("MY_SENDER_AGENT_NAME");
    ag.setAddress("MY_SENDER_AGENT_ADDRESS");
    msgprop.setSender(ag);
    // handle multi consumer case:
    if(recipients != null)
      msgprop.setRecipientList(recipients);
    System.out.println(msgprop.toString());
    AQMessage mesg = AQFactory.createAQMessage(msgprop);
byte[] rawPayload = "Example_Payload".getBytes();
mesg.setPayload(new oracle.sql.RAW(rawPayload));
```

30.6 Enqueuing Messages

After you create a message and set the message properties and payload, you can enqueue the message using the `enqueue` method of the `OracleConnection` interface. Before you enqueue the message, you can specify some enqueue options. The `AQEnqueueOptions` class enables you to specify the following enqueue options:

- Delivery mode: Specifies the delivery mode. Delivery mode can be set to either persistent (`ENQUEUE_PERSISTENT`) or buffered (`ENQUEUE_BUFFERED`).
- Retrieve Message ID: Specifies whether or not the message ID has to be retrieved from the server when the message has been enqueued. By default, the message ID is not retrieved.
- Transformation: Specifies a transformation that will be applied before enqueuing the message. The return type of the transformation function must match the type of the queue.

  > **Note**
  >
  > Transformations must be created in PL/SQL using `DBMS_TRANSFORM.CREATE_TRANSFORMATION(...)`.

- Visibility: Specifies the transactional behavior of the enqueue request. The default value for this option is `ENQUEUE_ON_COMMIT`. It indicates that the enqueue operation is part of the current transaction. `ENQUEUE_IMMEDIATE` indicates that the enqueue operation is an

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autonomous transaction, which commits at the end of the operation. For buffered messaging, you must use `ENQUEUE_IMMEDIATE`.

The following code snippet illustrates how to set the enqueue options and enqueue the message:

```
...
AQEnqueueOptions opt = new AQEnqueueOptions();opt.setRetrieveMessageId(true);
conn.enqueue(queueName, opt, mesg);
...
```

30.7 Dequeuing Messages

Enqueued messages can be dequeued using the `dequeue` method of the `OracleConnection` interface. Before you dequeue a message you must set the dequeue options. The `AQDequeueOptions` class enables you to specify the following dequeue options:

- Condition: Specifies a conditional expression based on the message properties, the message data properties, and PL/SQL functions. A dequeue condition is specified as a `Boolean` expression using syntax similar to the `WHERE` clause of a SQL query.
- Consumer name: If specified, only the messages matching the consumer name are accessed.

> **Note**
>
> If the queue is a single-consumer queue, do *not* set this option.

- Correlation: Specifies a correlation criterion (or search criterion) for the dequeue operation.
- Delivery Filter: Specifies the type of message to be dequeued. You dequeue buffered messages only (`DEQUEUE_BUFFERED`) or persistent messages only (`DEQUEUE_PERSISTENT`), which is the default, or both (`DEQUEUE_PERSISTENT_OR_BUFFERED`).
- Dequeue Message ID: Specifies the message identifier of the message to be dequeued. This can be used to dequeue a unique message whose ID is known.
- Dequeue mode: Specifies the locking behavior associated with the dequeue operation. It can take one of the following values:
  - `DequeueMode.BROWSE`: Message is dequeued without acquiring any lock.
  - `DequeueMode.LOCKED`: Message is dequeued with a write lock that lasts for the duration of the transaction.
  - `DequeueMode.REMOVE`: (default) Message is dequeued and deleted. The message can be retained in the queue based on the retention properties.
  - `DequeueMode.REMOVE_NO_DATA`: Message is marked as updated or deleted.
- Maximum Buffer Length: Specifies the maximum number of bytes that will be allocated when dequeuing a message from a `RAW` queue. The default maximum is `DEFAULT_MAX_PAYLOAD_LENGTH` but it can be changed to any other nonzero value. If the buffer is not large enough to contain the entire message, then the exceeding bytes will be silently ignored.
- Navigation: Specifies the position of the message that will be retrieved. It can take one of the following values:

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  - `NavigationOption.FIRST_MESSAGE`: The first available message matching the search criteria is dequeued.
  - `NavigationOption.NEXT_MESSAGE`: (default) The next available message matching the search criteria is dequeued. If the previous message belongs to a message group, then the next available message matching the search criteria in the message group is dequeued.
  - `NavigationOption.NEXT_TRANSACTION`: Messages in the current transaction group are skipped, and the first message of the next transaction group is dequeued. This setting can be used *only* if message grouping is enabled for the queue.

- Retrieve Message ID: Specifies whether or not the message identifier of the dequeued message needs to be retrieved. By default, it is not retrieved.
- Transformation: Specifies a transformation that will be applied after dequeuing the message. The source type of the transformation must match the type of the queue.

> **Note**
>
> Transformations must be created in PL/SQL using `DBMS_TRANSFORM.CREATE_TRANSFORMATION(...)`.

- Visibility: Specifies whether or not the message is dequeued as part of the current transaction. It can take one of the following values:
  - `VisibilityOption.ON_COMMIT`: (default) The dequeue operation is part of the current transaction.
  - `VisibilityOption.IMMEDIATE`: The dequeue operation is an autonomous transaction that commits at the end of the operation.

> **Note**
>
> The Visibility option is ignored in the `DequeueMode.BROWSE` dequeue mode. If the delivery filter is `DEQUEUE_BUFFERED` or `DEQUEUE_PERSISTENT_OR_BUFFERED`, then this option *must* be set to `VisibilityOption.IMMEDIATE`.

- Wait: Specifies the wait time for the dequeue operation, if none of the messages matches the search criteria. The default value is `DEQUEUE_WAIT_FOREVER` indicating that the operation waits forever. If set to `DEQUEUE_NO_WAIT`, then the operation does not wait. If a number is specified, then the dequeue operation waits for the specified number of seconds.

> **Note**
>
> If you use `DEQUEUE_WAIT_FOREVER`, then the dequeue operation will not return until a message that matches the search criterion is available in the queue. However, you can interrupt the dequeue operation by calling the `cancel` method on the `OracleConnection` object.

The following code snippet illustrates how to set the dequeue options and dequeue the message:

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```
...
AQDequeueOptions deqopt = new AQDequeueOptions();
deqopt.setRetrieveMessageId(true);
deqopt.setConsumerName(consumerName);
AQMessage msg = conn.dequeue(queueName,deqopt,queueType);
```

30.8 Examples: Enqueuing and Dequeuing

This section provides a few examples that illustrate how to enqueue and dequeue messages.

Example 30-2 illustrates how to enqueue a message, and Example 30-3 illustrates how to dequeue a message.

Example 30-2 Enqueuing a Single Message

This example illustrates how to obtain access to a queue, create a message, and enqueue it.

```
AQMessageProperties msgprop = AQFactory.createAQMessageProperties();
msgprop.setPriority(1);
msgprop.setExceptionQueue("EXCEPTION_QUEUE");
msgprop.setExpiration(0);
AQAgent agent = AQFactory.createAQAgent();
agent.setName("AGENTNAME");
agent.setAddress("AGENTADDRESS");
msgprop.setSender(agent);
AQMessage mesg = AQFactory.createAQMessage(msgprop);
mesg.setPayload(buffer); // where buffer is a byte array (for a RAW queue)
AQEnqueueOptions options = new AQEnqueueOptions();
conn.enqueue("HR.MY_QUEUE", options, mesg);
```

Example 30-3 Dequeuing a Single Message

This example illustrates how to obtain access to a queue, set the dequeue options, and dequeue the message.

```
AQDequeueOptions options = new AQDequeueOptions();
options.setDeliveryFilter(AQDequeueOptions.DeliveryFilter.BUFFERED);
AQMessage mesg = conn.dequeue("HR.MY_QUEUE", options, "RAW");
```


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31
Continuous Query Notification

This chapter describes how the Continuous Query Notification feature works.

This chapter describes the following topics:

- Overview of Continuous Query Notification
- Overview of Client Initiated Continuous Query Notification
- Creating a Registration
- Associating a Query with a Registration
- Notifying Database Change Events
- Deleting a Registration

31.1 Overview of Continuous Query Notification

Generally, a middle-tier data cache duplicates some data from the back-end database server, so that it can avoid redundant queries to the database. However, this is efficient only when the data rarely changes in the database. The data cache has to be updated or invalidated when the data changes in the database.

Starting from 11*g* Release 1, Oracle JDBC drivers provide support for the Continuous Query Notification feature of Oracle Database. Using this functionality, multitier systems can take advantage of the Continuous Query Notification feature to maintain a data cache as up-to-date as possible, by receiving invalidation events from the JDBC drivers.

The JDBC drivers can register SQL queries with the database and receive notifications in response to the following:

- DML or DDL changes on the objects associated with the queries
- DML or DDL changes that affect the result set

The notifications are published when the DML or DDL transaction commits (changes made in a local transaction do not generate any event until they are committed).

To use Oracle JDBC driver support for Continuous Query Notification, perform the following:

1. Registration: You first need to create a registration.
2. Query association: After you have created a registration, you can associate SQL queries with it. These queries are part of the registration.
3. Notification: Notifications are created in response to changes in tables or result set. Oracle database communicates these notifications to the JDBC drivers through a dedicated network connection and JDBC drivers convert these notifications to Java events.

Also, you need to grant the `CHANGE NOTIFICATION` privilege to the user. For example, if you connect to the database using the `HR` user name, then you need to run the following command in the database:

```
grant change notification to HR;
```


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31.2 Overview of Client Initiated Continuous Query Notification

Starting from Oracle Database Release 19c, the JDBC Thin driver supports the Client Initiated Continuous Query Notification feature. In this case, the client application initiates a connection to the database server for receiving notifications.

A client application first initiates a new database connection before creating a Continuous Query Notification registration. When the application creates a registration, the JDBC driver internally starts a new thread and creates a new connection with the database server. The database server then uses this new connection to send change notifications to the client.

By default, this feature is disabled for an on-premise database. You must set the `OracleConnection.DCN_CLIENT_INIT_CONNECTION` to true for enabling this feature.

> **See Also**
>
> Continuous Query Notification Registration Options

31.3 Creating a Registration

Creating a CQN registration is a one-time process and is done outside the currently used transaction. The API for creating a registration in the server is executed in its own transaction and is committed immediately.

You need a JDBC connection to create a registration. However, the registration is not attached to the connection. You can close the connection after creating a registration, and the registration survives. In an Oracle RAC environment, a registration is a persistent entity that exists on all nodes. The registration exists in the Database. So, even if a node goes down, the registration continues to exist and is notified when the tables change.

There are two ways to create a registration:

- The JDBC-style of registration: Use the JDBC driver to create a registration on the server. The JDBC driver launches a new thread that listens to notifications from the server (through a dedicated channel) and converts these notification messages into Java events. The driver then notifies all the listeners registered with this registration.
- The PL/SQL-style of registration: If you want a PL/SQL stored procedure to handle the notifications, then create a PL/SQL-style registration. As in the JDBC-style of registration, the JDBC drivers enable you to attach statements (queries) to this registration. However the JDBC drivers do not get notifications from the server because the notifications are handled by the PL/SQL stored procedure.

> **Note**
>
> This approach is useful only for nonmultithreaded languages, such as PHP.

There is no way to remove one particular object (table) from an existing registration. A workaround would be to either create a new registration without this object or ignore the events that are related to this object.

You can use the `registerDatabaseChangeNotification` method of the `oracle.jdbc.OracleConnection` interface to create a JDBC-style of registration. You can set

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certain registration options through the `options` parameter of this method. The "Continuous Query Notification Registration Options" table in the following section lists some of the registration options that can be set. To set these options, use the `java.util.Properties` object. These options are defined in the `oracle.jdbc.OracleConnection` interface. The registration options have a direct impact on the notification events that the JDBC drivers will create. The example (at the end of this chapter) illustrates how to use the Continuous Query Notification feature.

The `registerDatabaseChangeNotification` method creates a new database change registration in the database server with the given options. It returns a `DatabaseChangeRegistration` object, which can then be used to associate a statement with this registration. It also opens a listener socket that will be used by the database to send notifications.

> **Note**
>
> If a listener socket (created by a different registration) exists, then this socket is used by the new database change registration as well.

31.3.1 Continuous Query Notification Registration Options

The following table lists the Continuous Query Notification Registration Options:

Table 31-1 Continuous Query Notification Registration Options

Option	Description
`DCN_IGNORE_DELETEOP`	If set to `true`, `DELETE` operations will not generate any database change event.
`DCN_IGNORE_INSERTOP`	If set to `true`, `INSERT` operations will not generate any database change event.
`DCN_IGNORE_UPDATEOP`	If set to `true`, `UPDATE` operations will not generate any database change event.
`DCN_NOTIFY_CHANGELAG`	Specifies the number of transactions by which the client is willing to lag behind. **Note:** If this option is set to any value other than `0`, then `ROWID` level granularity of information will not be available in the events, even if the `DCN_NOTIFY_ROWIDS` option is set to `true`.
`DCN_NOTIFY_ROWIDS`	Database change events will include row-level details, such as operation type and `ROWID`.
`DCN_QUERY_CHANGE_NOTIFICATION`	Activates query change notification instead of object change notification. **Note:** This option is available only when running against an 11.0 database.
`DCN_CLIENT_INIT_CONNECTION`	Specifies Client Initiated Continuous Query Notification, where the client application initiates a database connection, which the server uses to send change notifications to the client.
`NTF_LOCAL_HOST`	Specifies the IP address of the computer that will receive the notifications from the server.
`NTF_LOCAL_TCP_PORT`	Specifies the TCP port that the driver should use for the listener socket.
`NTF_QOS_PURGE_ON_NTFN`	Specifies if the registration should be expunged on the first notification event.
`NTF_QOS_RELIABLE`	Specifies whether or not to make the notifications persistent, which comes at a performance cost.
`NTF_TIMEOUT`	Specifies the time in seconds after which the registration will be automatically expunged by the database.

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If there exists a registration, then you can also use the `getDatabaseChangeRegistration` method to map the existing registration with a new `DatabaseChangeRegistration` object. This method is particularly useful if you have created a registration using PL/SQL and want to associate a statement with it.

31.4 Associating a Query with a Registration

After you have created a registration or mapped to an existing registration, you can associate a query with it. Like creating a registration, associating a query with a registration is a one-time process and is done outside of the currently used registration. The query will be associated even if the local transaction is rolled back.

You can associate a query with registration using the `setDatabaseChangeRegistration` method defined in the `OracleStatement` class. This method takes a `DatabaseChangeRegistration` object as parameter. The following code snippet illustrates how to associate a query with a registration:

```
...
// conn is an OracleConnection object.
// prop is a Properties object containing the registration options.
DatabaseChangeRegistration dcr = conn.registerDatabaseChangeNotifictaion(prop);
...
Statement stmt = conn.createStatement();
// associating the query with the registration
((OracleStatement)stmt).setDatabaseChangeRegistration(dcr);
// any query that will be executed with the 'stmt' object will be associated with
// the registration 'dcr' until 'stmt' is closed or
// '((OracleStatement)stmt).setDatabaseChangeRegistration(null);' is executed.
...
```

31.5 Notifying Database Change Events

To receive Continuous Query Notifications, attach a listener to the registration. When a database change event occurs, the database server notifies the JDBC driver. The driver then constructs a new Java event, identifies the registration to be notified, and notifies the listeners attached to the registration. The event contains the object ID of the database object that has changed and the type of operation that caused the change. Depending on the registration options, the event may also contain row-level detail information. The listener code can then use the event to make decisions about the data cache.

> **Note**
>
> The listener code must not slow down the JDBC notification mechanism. If the code is time-consuming, for example, if it refreshes the data cache by querying the database, then it needs to be executed within its own thread.

You can attach a listener to a registration using the `addListener` method. The following code snippet illustrates how to attach a listener to a registration:

```
...
// conn is an OracleConnection object.
// prop is a Properties object containing the registration options.
DatabaseChangeRegistration dcr = conn.registerDatabaseChangeNotifictaion(prop);
...
// Attach the listener to the registration.
```


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```
// Note: DCNListener is a custom listener and not a predefined or standard
// lsiener
DCNListener list = new DCNListener();
dcr.addListener(list);
...
```

31.6 Deleting a Registration

You need to explicitly unregister a registration to delete it from the server and release the resources in the driver.

You can unregister a registration using a connection different from one that was used for creating it. To unregister a registration, you can use the `unregisterDatabaseChangeNotification` method defined in `oracle.jdbc.OracleConnection`.

You must pass the `DatabaseChangeRegistration` object as a parameter to this method. This method deletes the registration from the server and the driver and closes the listener socket.

If the registration was created outside of JDBC, say using PL/SQL, then you must pass the registration ID instead of the `DatabaseChangeRegistration` object. The method will delete the registration from the server, however, it does not free any resources in the driver.

The example in this section demonstrates how to use the Continuous Query Notification feature. In this example, the `HR` user is connecting to the database. Therefore in the database you need to grant the following privilege to the user:

```
grant change notification to HR;
```

This code will also work with Oracle Database 10*g* Release 2 (10.2). This code uses table registration. That is, when you register a `SELECT` query, what you register is the name of the tables involved and not the query itself. In other words, you might select one single row of a table and if another row is updated, you will be notified although the result of your query has not changed.

In this example, if you leave the registration open instead of closing it, then the Continuous Query Notification thread continues to run. Now if you run a DML query that changes the `HR.DEPARTMENTS` table and commit it, say from SQL*Plus, then the Java program prints the notification.

Example 31-1 Continuous Query Notification

```
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;
import java.util.Properties;
import oracle.jdbc.OracleConnection;
import oracle.jdbc.OracleDriver;
import oracle.jdbc.OracleStatement;
import oracle.jdbc.dcn.DatabaseChangeEvent;
import oracle.jdbc.dcn.DatabaseChangeListener;
import oracle.jdbc.dcn.DatabaseChangeRegistration;

public class DBChangeNotification
{
  static final String USERNAME= "HR";
  static final String PASSWORD= "hr";
  static String URL;

  public static void main(String[] argv)
  {
```


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```
    if(argv.length < 1)
    {
      System.out.println("Error: You need to provide the URL in the first argument.");
      System.out.println("  For example: > java -classpath .:ojdbc11.jar
DBChangeNotification \"jdbc:oracle:thin:
@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)(HOST=yourhost.yourdomain.com)(PORT=5221))
(CONNECT_DATA=
(SERVICE_NAME=orcl)))\"");

      System.exit(1);
    }
    URL = argv[0];
    DBChangeNotification demo = new DBChangeNotification();
    try
    {
      demo.run();
    }
    catch(SQLException mainSQLException )
    {
      mainSQLException.printStackTrace();
    }
  }

  void run() throws SQLException
  {
    OracleConnection conn = connect();

    // first step: create a registration on the server:
    Properties prop = new Properties();

    // if connected through the VPN, you need to provide the TCP address of the client.
    // For example:
    // prop.setProperty(OracleConnection.NTF_LOCAL_HOST,"14.14.13.12");

    // Ask the server to send the ROWIDs as part of the DCN events (small performance
    // cost):
    prop.setProperty(OracleConnection.DCN_NOTIFY_ROWIDS,"true");
//
//Set the DCN_QUERY_CHANGE_NOTIFICATION option for query registration with finer
granularity.
 prop.setProperty(OracleConnection.DCN_QUERY_CHANGE_NOTIFICATION,"true");

    // The following operation does a roundtrip to the database to create a new
    // registration for DCN. It sends the client address (ip address and port) that
    // the server will use to connect to the client and send the notification
    // when necessary. Note that for now the registration is empty (we haven't registered
    // any table). This also opens a new thread in the drivers. This thread will be
    // dedicated to DCN (accept connection to the server and dispatch the events to
    // the listeners).
    DatabaseChangeRegistration dcr = conn.registerDatabaseChangeNotification(prop);

    try
    {
      // add the listenerr:
      DCNDemoListener list = new DCNDemoListener(this);
      dcr.addListener(list);

      // second step: add objects in the registration:
      Statement stmt = conn.createStatement();
      // associate the statement with the registration:
      ((OracleStatement)stmt).setDatabaseChangeRegistration(dcr);
      ResultSet rs = stmt.executeQuery("select * from dept where deptno='45'");
```


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```
      while (rs.next())
      {}
      String[] tableNames = dcr.getTables();
      for(int i=0;i<tableNames.length;i++)
        System.out.println(tableNames[i]+" is part of the registration.");
      rs.close();
      stmt.close();
    }
    catch(SQLException ex)
    {
      // if an exception occurs, we need to close the registration in order
      // to interrupt the thread otherwise it will be hanging around.
      if(conn != null)
        conn.unregisterDatabaseChangeNotification(dcr);
      throw ex;
    }
    finally
    {
      try
      {
        // Note that we close the connection!
        conn.close();
      }
      catch(Exception innerex){ innerex.printStackTrace(); }
    }

    synchronized( this )
    {
      // The following code modifies the dept table and commits:
      try
      {
        OracleConnection conn2 = connect();
        conn2.setAutoCommit(false);
        Statement stmt2 = conn2.createStatement();
        stmt2.executeUpdate("insert into dept (deptno,dname) values ('45','cool dept')",
Statement.RETURN_GENERATED_KEYS);
        ResultSet autoGeneratedKey = stmt2.getGeneratedKeys();
        if(autoGeneratedKey.next())
          System.out.println("inserted one row with
ROWID="+autoGeneratedKey.getString(1));
        stmt2.executeUpdate("insert into dept (deptno,dname) values ('50','fun dept')",
Statement.RETURN_GENERATED_KEYS);
        autoGeneratedKey = stmt2.getGeneratedKeys();
        if(autoGeneratedKey.next())
          System.out.println("inserted one row with
ROWID="+autoGeneratedKey.getString(1));
        stmt2.close();
        conn2.commit();
        conn2.close();
      }
      catch(SQLException ex) { ex.printStackTrace(); }

      // wait until we get the event
      try{ this.wait();} catch( InterruptedException ie ) {}
    }

    // At the end: close the registration (comment out these 3 lines in order
    // to leave the registration open).
    OracleConnection conn3 = connect();
    conn3.unregisterDatabaseChangeNotification(dcr);
    conn3.close();
  }
```


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```
  /**
   * Creates a connection the database.
   */
  OracleConnection connect() throws SQLException
  {
    OracleDriver dr = new OracleDriver();
    Properties prop = new Properties();
    prop.setProperty("user",DBChangeNotification.USERNAME);
    prop.setProperty("password",DBChangeNotification.PASSWORD);
    return (OracleConnection)dr.connect(DBChangeNotification.URL,prop);
  }
}
/**
 * DCN listener: it prints out the event details in stdout.
 */
class DCNDemoListener implements DatabaseChangeListener
{
  DBChangeNotification demo;
  DCNDemoListener(DBChangeNotification dem)
  {
    demo = dem;
  }
  public void onDatabaseChangeNotification(DatabaseChangeEvent e)
  {
    Thread t = Thread.currentThread();
    System.out.println("DCNDemoListener: got an event ("+this+" running on thread
"+t+")");
    System.out.println(e.toString());
    synchronized( demo ){ demo.notify();}
  }
}
```


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Part VI
High Availability

This section provides information about the high availability features of Oracle Database Release 23ai.

Part VI contains the following chapters:

- Transaction Guard for Java
- Application Continuity for Java
- Oracle JDBC Support for FAN Events
- Transparent Application Failover
- Single Client Access Name

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32

Transaction Guard for Java

The Transaction Guard feature of Oracle Database provides a generic infrastructure for at-most-once execution during planned and unplanned outages and duplicate submissions. This chapter discusses Transaction Guard for Java in the following sections:

- Overview of Transaction Guard for Java
- Transaction Guard Support for XA Transactions
- Transaction Guard for Java APIs
- Complete Example:Using Transaction Guard APIs
- About Using Server-Side Transaction Guard APIs

32.1 Overview of Transaction Guard for Java

For most of the current applications, determining the outcome of the last commit operation in a guaranteed and scalable manner, following a communication failure to the server, is an unsolved problem. In many cases, the applications prompt the end users to follow certain steps to avoid resubmitting duplicate requests. For example, some applications warn users not to click the Submit button twice because if it is not followed, then users may unintentionally purchase the same items twice and submit multiple payments for the same invoice.

To solve this problem, Transaction Guard for Java provides transaction idempotence, that is, every transaction has at-most-once execution that prevents applications from submitting duplicate transactions. You can tag every transaction with a Logical Transaction Identifier (`LTXID`), which the application can use after the occurrence of a failure to verify whether the transaction had committed before the failure or not. For example, if the commit calls do not return, then using the `LTXID`, the application can find out whether the calls succeeded or not.

The Application Continuity for Java feature uses Transaction Guard for Java internally, which enables transparent session recovery and replay of SQL statements (queries and DMLs) since the beginning of the in-flight transaction. Application Continuity enables recovery of work after the occurrence of a planned or unplanned outage and Transaction Guard for Java ensures transaction idempotence. When an outage occurs, the recovery restores the state exactly as it was before the failure occurred.

Related Topics

- Application Continuity for Java
  The outages of the underlying software, hardware, communications, and storage layers can cause application execution to fail. In the worst cases, the middle-tier servers may need to be restarted to deal with a logon storm, which is a sudden increase in the number of client connection requests.

32.2 Transaction Guard Support for XA Transactions

Starting from Oracle Database 12*c* Release 2 (12.2.0.1), Transaction Guard provides support for XA transactions for one-phase commit optimization, read-only optimization, and promotable XA. Transaction Guard with XA provides safe replay following recoverable outages for XA

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transactions. With the addition of XA support, Transaction Managers can now provide replay with idempotence enforced more easily using Transaction Guard.

> **Note**
>
> For using Transaction Guard with XA, during session check-out from the connection pool, you must verify that the database version is Oracle 12*c* Release 2 (12.2.0.1) or later, and Transaction Guard is enabled.

A new server protocol provides a guaranteed commit outcome when the commit is one-phase managed by the database, and switches to a disabled mode while the Transaction Manager coordinates a transaction for that session. The new protocol sets a status flag in the LTXID that validates and invalidates access to the LTXID, based on the current transaction owner.

The protocol is intelligent in its handling that XA can encompass many sessions and many branches for the one XA transaction. As a further challenge, once a branch is suspended, a session is available for different transactions, while the original transaction remains active. There is no requirement to prepare or commit XA transactions on the same session or RAC instance that created the original branches. Transaction Guard for XA uses the following two new methods for handling commit outcome at the database for one-phase XA transactions, while the Transaction Manager continues to handle commit-outcome for two-phase transactions:

- Using the first method, the driver marks the LTXID provisional until a recoverable error, or any other named condition, occurs on that session. When a recoverable error (or any other condition) occurs, the LTXID at the client is marked final. The guaranteed commit outcome is provided only when the LTXID is final at the client, and at the server that LTXID has a VALID status, indicating that the database owns that transaction. Any other access attempt returns an error.
- Using the second method, the client driver does not provide the LTXID to the application until a recoverable error, or other named condition, occurs on that session.

32.3 How to Use Transaction Guard with XA

This section contains the following sections:

Obtaining the Commit Outcome with Promotable XA

For local transactions, the request obtains an LTXID as the transaction key, when there is a recoverable exception. When a second branch starts, then the request is promoted to XA, or converted to XA, and a Global Transaction ID (GTRID) is allocated to it. If a recoverable outage occurs during commit processing, where the application does not receive a reply from the Transaction Manager, then the application can ask a Transaction Manager for the outcome. Most requests to the database use either local transactions or single branch optimization. When you use either local transactions or promotable XA, then there is no overhead in round trips and management for XA, because the majority of the transactions are local. The workflow of these transactions follows:

1. Prior to converting to XA, transaction processing is local. Authentication, `SELECT` statements, and local transactions carry and use the LTXID of the local transaction.
2. The Transaction Manager allocates a GTRID to the transaction only when it starts to use XA due to opening a second branch of the transaction.

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3. Following a recoverable error, when the application does not receive a commit outcome, if the transaction is local, then the Transaction Manager can use the LTXID with the `GET_LTXID_OUTCOME` procedure to retrieve the commit outcome and return `COMMITTED` or `UNCOMMITTED` outcome to the application.

Replaying if Promotable XA Is Added

Before being promoted, promotable XA supports RDBMS commits through calls and settings that are not supported by static XA. These calls include auto-commit mode, DDL, DCL, COMMIT embedded in PL/SQL, and COMMIT through remote procedure calls. The COMMIT outcome for these user calls and modes is controlled by the RDBMS, and following an error, the commit outcome can be found using Transaction Guard.

Until promoted, the Transaction Manager is unaware whether the request has issued any COMMIT or not. If the Transaction Manager wishes to replay a request following a recoverable error, then the Transaction Manager must determine if any RDBMS COMMIT has occurred. If any RDBMS COMMIT occurs, or can occur, then replay does not happen. The `GET_LTXID_OUTCOME` procedure is insufficient in determining this because the procedure only reports the current transaction outcome. If the LTXID is changed, then the transaction is committed. So, the invocation of the LTXID callback indicates that the transaction is committed.

32.4 Transaction Guard for Java APIs

This section discusses the APIs associated with Transaction Guard for Java for the following activities:

- Retrieving the Logical Transaction Identifiers
- Retrieving the Updated Logical Transaction Identifiers

32.4.1 Retrieving the Logical Transaction Identifiers

Use the `getLogicalTransactionId` method of the `oracle.jdbc.OracleConnection` interface to retrieve the current Logical Transaction Identifiers that are sent by the server. This method call does not make a database round-trip.

Example

```
OracleConnection oconn = (OracleConnection) ods.getConnection();
...
// Getting the 1st LTXID after connecting
LogicalTransactionId firstLtxid = oconn.getLogicalTransactionId();
```

32.4.2 Retrieving the Updated Logical Transaction Identifiers

Use the `oracle.jdbc.LogicalTransactionIdEventListener` interface for receiving updates to Logical Transaction Identifiers. You must implement this interface in your application to process the Logical Transaction Identifier events.

32.4.2.1 Registering Event Listeners

Use the `addLogicalTransactionIdEventListener` method to register a listener to the Logical Transaction Identifier events.

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Example

```
OracleConnection oconn = (OracleConnection) ods.getConnection();
...
// The subsequent LTXID updates can be obtained through the listener
oconn.addLogicalTransactionIdEventListener(this);
```

You can also use the `addLogicalTransactionIdEventListener(LogicalTransactionIdEventListener listener, java.util.concurrent.Executor executor)` method to register a listener with an executor.

32.4.2.2 Unregistering Event Listeners

Use the `removeLogicalTransactionIdEventListener` method to unregister a listener from the Logical Transaction Identifier events.

Example

```
OracleConnection oconn = (OracleConnection) ods.getConnection();
...
// The subsequent LTXID updates can be obtained through the listener
oconn.removeLogicalTransactionIdEventListener(this);
```

32.5 Complete Example:Using Transaction Guard APIs

The following is a complete example using the Transaction Guard APIs.

```
import oracle.jdbc.pool.OracleDataSource;
import oracle.jdbc.OracleConnection;
import oracle.jdbc.LogicalTransactionId;
import oracle.jdbc.LogicalTransactionIdEvent;
import oracle.jdbc.LogicalTransactionIdEventListener;

public class transactionGuardExample
{
      ...
      ...
      OracleDataSource ods = new OracleDataSource();
      ods.setURL(url);
      ods.setUser("user");
      ods.setPassword("password");

      OracleConnection oconn = (OracleConnection) ods.getConnection();

      // Getting the 1st LTXID after connecting
      LogicalTransactionId firstLtxid = oconn.getLogicalTransactionId();

      // The subsequent LTXID updates can be obtained via the listener
      oconn.addLogicalTransactionIdEventListener(this);
  }

public class LtxidListenerImpl
  implements LogicalTransactionIdEventListener
{
  ...

  public void onLogicalTransactionIdEvent(LogicalTransactionIdEvent ltxidEvent)
```


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```
    {
      LogicalTransactionId newLtxid = ltxidEvent.getLogicalTransactionId();
      // process newLtxid ......
    }
  }
```

32.6 About Using Server-Side Transaction Guard APIs

The DBMS_APP_CONT package contains the GET_LTXID_OUTCOME procedure that contains the server-side Transaction Guard APIs. This procedure forces the outcome of a transaction. If the transaction is not committed, then a fake transaction is committed. Otherwise, the state of the transaction is returned. By default, the EXECUTE privilege for this package is granted to Database Administrators.

Syntax

```
PROCEDURE GET_LTXID_OUTCOME(CLIENT_LTXID        IN  RAW,
                            committed           OUT BOOLEAN,
                            USER_CALL_COMPLETED OUT BOOLEAN);
```

Input Parameter

CLIENT_LTXID specifies the LTXID from the client driver.

Output Parameter

COMMITTED specifies that the transaction is committed.

USER_CALL_COMPLETED specifies that the user call, which committed the transaction, is complete.

Exceptions

SERVER_AHEAD is thrown when the server is ahead of the client. So, the transaction is an old transaction and must have already been committed.

CLIENT_AHEAD is thrown when the client is ahead of the server. This can only happen if the server is flashed back or the LTXID is corrupted. In either of these situations, the outcome cannot be determined.

ERROR is thrown when an error occurs during processing and the outcome cannot be determined. It specifies the error code raised during the execution of the current procedure.

Example

Example 32-1 shows how you can call the GET_LTXID_OUTCOME procedure and find out the outcome of an LTXID:

Example 32-1 Finding Out the Outcome of an LTXID

```
...
OracleConnection oconn = (OracleConnection) ods.getConnection();
LogicalTransactionId ltxid = oconn.getLogicalTransactionId();
boolean committed = false;
boolean call_completed = false;

try
{
  CallableStatement cstmt = oconn.prepareCall(GET_LTXID_OUTCOME);
  cstmt.setObject(1, ltxid);
```


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```
  cstmt.registerOutParameter(2, OracleTypes.BIT);
  cstmt.registerOutParameter(3, OracleTypes.BIT);

  cstmt.execute();

  committed = cstmt.getBoolean(2);
  call_completed = cstmt.getBoolean(3);

  System.out.println("LTXID committed ? " + committed);
  System.out.println("User call completed ? " + call_completed);
}
catch (SQLException sqlexc)
{
  System.out.println("Calling GET_LTXID_OUTCOME failed");
  sqlexc.printStackTrace();
}
```


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33

Application Continuity for Java

The outages of the underlying software, hardware, communications, and storage layers can cause application execution to fail. In the worst cases, the middle-tier servers may need to be restarted to deal with a logon storm, which is a sudden increase in the number of client connection requests.

To overcome such problems, Oracle Database 12*c* Release 1 (12.1) introduced the Application Continuity feature that masks database outages to the application and end users are not exposed to such outages.

> **Note**
>
> - You must use Transaction Guard for using Application Continuity.
> - Explicit switch of container and service in applications through the `ALTER SESSION SET CONTAINER` statement is not supported with Application Continuity.

Application Continuity provides a general purpose, application-independent solution that enables recovery of work from an application perspective, after the occurrence of a planned or unplanned outage. The outage can be related to system, communication, or hardware following a repair, a configuration change, or a patch application.

This chapter discusses the JDBC aspect of Application Continuity in the following sections:

- About Configuring Oracle JDBC for Application Continuity for Java
- About Configuring Oracle Database for Application Continuity for Java
- Application Continuity with DRCP
- Application Continuity Support for XA Data Source
- About Identifying Request Boundaries in Application Continuity for Java
- Support for Transparent Application Continuity
- Establishing the Initial State Before Application Continuity Replays
- About Delaying the Reconnection in Application Continuity for Java
- About Retaining Mutable Values in Application Continuity for Java
- Application Continuity Statistics
- About Disabling Replay in Application Continuity for Java

Related Topics

- Transaction Guard for Java

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33.1 About Configuring Oracle JDBC for Application Continuity for Java

For configuring Oracle JDBC on the client-side, you must specify an Oracle JDBC driver data source, and set the necessary properties on this data source. The data source depends on the Oracle JDBC driver version that you use.

- For Oracle JDBC driver 23ai, Application Continuity is auto-enabled for all the driver data sources. To support Application Continuity, all you need is to connect to a database service with AC/TAC enabled.

  To disable Application Continuity on any driver data source, you can perform any of the following steps:

  – Specify `oracle.jdbc.enableACSupport=false` as a Java system property
  – Specify `oracle.jdbc.enableACSupport=false` as a driver connection property
  – Set `?oracle.jdbc.enableACSupport=false` in the URL
- For using Oracle JDBC driver 19c or older, you must use `oracle.jdbc.replay.OracleDataSourceImpl` for Application Continuity.

> **Note**
>
> Regardless of the Oracle JDBC driver version, the configuration of any driver data source or associated properties (including connection properties) is usually specific to the application server, container, or framework that you are using, for example, WebLogic, WebSphere, JBoss, Spring, Tomcat, and so on. If you use a connection pool, then this data source is usually specified as a connection factory class for the connection pool.

> **See Also**
>
> Application Continuity Support for XA Data Source, if you use XA transactions, or XA data source for local transactions.

The following code snippet illustrates the usage of `oracle.jdbc.datasource.impl.OracleDataSource` in a standalone JDBC application:

```
import java.sql.Connection;
import oracle.jdbc.datasource.impl.OracleDataSource;
......

{
  ......
  OracleDataSource ods = new OracleDataSource();
  ods.setUser(user);
  ods.setPassword(passwd);
  ods.setURL(url);
  ......  // Other data source configuration like callback, timeouts, etc.

  Connection conn = ods.getConnection();
```


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```
  conn.beginRequest();  // Explicit request begin
  ......  // JDBC calls protected by Application Continuity
  conn.endRequest();  // Explicit request end
  conn.close();
}
```

You must remember the following points while using the connection URL:

- Always use the thin driver in the connection URL.
- Always connect to a service. Never use `instance_name` or SID because these do not direct to known good instances and SID is deprecated.
- If the addresses in the `ADDRESS_LIST` at the client does not match the `REMOTE_LISTENER` setting for the database, then it does not connect showing `services cannot be found`. So, the addresses in the `ADDRESS_LIST` at the client *must* match the `REMOTE_LISTENER` setting for the database:
  - If `REMOTE_LISTENER` is set to the `SCAN_VIP`, then the `ADDRESS_LIST` uses `SCAN_VIP`
  - If `REMOTE_LISTENER` is set to the host VIPs, then the `ADDRESS_LIST` uses the same host VIPs
  - If `REMOTE_LISTENER` is set to both `SCAN_VIP` and host VIPs, then the `ADDRESS_LIST` uses `SCAN_VIP` and the same host VIPs

  > **Note**
  >
  > For Oracle clients prior to release 11.2, the `ADDRESS_LIST` must be upgraded to use SCAN, which means expanding the `ADDRESS_LIST` to three `ADDRESS` entries corresponding to the three SCAN IP addresses.
  >
  > If such clients connect to a database that is upgraded from an earlier release through Database AutoUpgrade, then you must retain the `ADDRESS_LIST` of these clients set to the HOST VIPs. However, if `REMOTE_LISTENER` is changed to `ONLY SCAN`, or the clients are moved to a newly installed Oracle Database 12*c* Release 1, where `REMOTE_LISTENER` is `ONLY SCAN`, then they do not get a complete service map, and may not always be able to connect.

- Set `RETRY_COUNT`, `RETRY_DELAY`, `CONNECT_TIMEOUT`, and `TRANSPORT_CONNECT_TIMEOUT` parameters in the connection string. This is a general recommendation for configuring the JDBC thin driver connections, starting from Oracle Database Release 12.1.0.2. These settings improve acquiring new connections at run time, at replay, and during work drains for planned outages.

  The `CONNECT_TIMEOUT` parameter is equivalent to the `SQLNET.OUTBOUND_CONNECT_TIMEOUT` parameter in the `sqlnet.ora` file and applies to the full connection. The `TRANSPORT_CONNECT_TIMEOUT` parameter applies as per the `ADDRESS` parameter. If the service is not registered for a failover or restart, then retrying is important when you use SCAN. For example, for using remote listeners pointing to SCAN addresses, you should use the following settings:

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> **Note**
>
> In the following code snippets, the `TRANSPORT_CONNECT_TIMEOUT` parameter is set to 3. However, if you are using 12.2.0.1 JDBC driver in your application, without the required patch that fixes bug 25977056, then you must set the `TRANSPORT_CONNECT_TIMEOUT` parameter to 3000.

```
jdbc:oracle:thin:@(DESCRIPTION =
 (TRANSPORT_CONNECT_TIMEOUT=3)
 (RETRY_COUNT=20)(RETRY_DELAY=3s)(FAILOVER=ON)
 (ADDRESS_LIST =(ADDRESS=(PROTOCOL=tcp)
  (HOST=CLOUD-SCANVIP.example.com)(PORT=5221))
 (CONNECT_DATA=(SERVICE_NAME=orcl)))

REMOTE_LISTENERS=CLOUD-SCANVIP.example.com:5221
```

Similarly, for using remote listeners pointing to VIPs at the database, you should use the following settings:

```
jdbc:oracle:thin:@(DESCRIPTION =
(TRANSPORT_CONNECT_TIMEOUT=3)
(CONNECT_TIMEOUT=60)(RETRY_COUNT=20)(RETRY_DELAY=3s)(FAILOVER=ON)
 (ADDRESS_LIST=
 (ADDRESS=(PROTOCOL=tcp)(HOST=CLOUD-VIP1.example.com)(PORT=5221) )
(ADDRESS=(PROTOCOL=tcp)(HOST=CLOUD-VIP2.example.com)(PORT=5221) )
 (ADDRESS=(PROTOCOL=tcp)(HOST=CLOUD-VIP3.example.com)(PORT=5221) ))
(CONNECT_DATA=(SERVICE_NAME=orcl)))

REMOTE_LISTENERS=CLOUD-VIP1.example.com:5221
```

> **See Also**
>
> - *Oracle Database Net Services Reference* for more information about local naming parameters
> - *Oracle Real Application Clusters Administration and Deployment Guide*

Related Topics

- Data Sources and URLs

33.1.1 Support for Concrete Classes with Application Continuity

Starting from Oracle Database Release 18c, the JDBC driver supports concrete classes with Application Continuity.

The classes are the following:

- `oracle.sql.CLOB`
- `oracle.sql.NCLOB`
- `oracle.sql.BLOB`
- `oracle.sql.BFILE`
- `oracle.sql.STRUCT`
- `oracle.sql.REF`

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- `oracle.sql.ARRAY`

The only concrete classes in the `oracle.sql` package, which are not supported with Application Continuity, are:

- `oracle.sql OPAQUE`
- `oracle.sql.ANYDATA`
- `oracle.sql.JAVA_STRUCT`

Although the Oracle JDBC driver supports the concrete classes present in the `oracle.sql` package with Application Continuity, Oracle strongly recommends that you update your applications to use the Java interfaces instead. These interfaces can be the standard JDBC `java.sql` interfaces, or Oracle JDBC extension interfaces in the `oracle.jdbc` package, such as `oracle.jdbc.OracleBlob`, `oracle.jdbc.OracleClob`, and so on.

33.1.2 About Using LONG and LONG RAW columns with Application Continuity

Typically, Oracle recommends using LOB columns instead of LONG and LONG RAW columns. This also applies to Application Continuity.

If you have one or more LONG or LONG RAW columns in your table, then the JDBC driver transfers those to the client in streaming mode, when a query selects those columns. In streaming mode, the JDBC driver does not read the column data from the network for LONG or LONG RAW columns, until required. As a result of this, a query involving one or more such columns can result in a replay failure. So, if there is a situation when you cannot avoid using such columns, then perform the following tasks to resolve the issue:

> **See Also**
>
> About Streaming LONG or LONG RAW Columns

- Use the `defineColumnType` method to redefine the type of the LONG or LONG RAW column. For example, if you redefine the LONG or LONG RAW column as VARCHAR or VARBINARY type, then the driver will not stream the data automatically.
- Declare the types of all the columns involved in the query.

> **Note**
>
> If you redefine the column types with the `defineColumnType` method, then you must declare the types of all the columns involved in the query. If you do not do so, then the `executeQuery` method will fail.

- Cast the Statement object to `oracle.jdbc.OracleStatement`.

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33.2 About Configuring Oracle Database for Application Continuity for Java

You must configure Oracle Database for using Application Continuity for Java.

For using Application Continuity, you must have the following configuration:

- Use Oracle Database 12*c* Release 1 (12.1) or later
- If you are using Oracle Real Application Clusters (Oracle RAC) or Oracle Data Guard, then ensure that FAN is configured with Oracle Notification System (ONS) to communicate with Oracle WebLogic Server or the Universal Connection Pool (UCP)
- Use an application service for all database work. To create the service you must:
  - Run the `SRVCTL` command if you are using Oracle RAC
  - Use the `DBMS_SERVICE` package if you are not using Oracle RAC
- Set the required properties on the service for replay and load balancing. For example, set:
  - `aq_ha_notifications = TRUE` for enabling FAN notification
  - `FAILOVER_TYPE = TRANSACTION` or `FAILOVER_TYPE = AUTO` for using Application Continuity
  - `COMMIT_OUTCOME` = `TRUE` for enabling Transaction Guard
  - `REPLAY_INITIATION_TIMEOUT = 900` for setting the duration in seconds for which replay will occur
  - `FAILOVER_RETRIES = 30` for specifying the number of connection retries for each replay
  - `FAILOVER_DELAY = 10` for specifying the delay in seconds between connection retries
  - `GOAL = SERVICE_TIME`, if you are using Oracle RAC, then this is a recommended setting
  - `CLB_GOAL = LONG`, typically useful for closed workloads. If you are using Oracle RAC, then this is a recommended setting. For most of the other workloads, `SHORT` is the recommended setting.
- Do not use the database service, that is, the default service corresponding to the `DB_NAME` or `DB_UNIQUE_NAME`. This service is reserved for Oracle Enterprise Manager and for DBAs. Oracle does not recommend the use of the database service for high availability because this service cannot be:
  - Enabled and disabled
  - Relocated on Oracle RAC
  - Switched over to Oracle Data Guard

See Also

- Configuration Examples Related to Application Continuity for Java
- Configuring Oracle Database for Application Continuity

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33.3 Application Continuity with DRCP

Oracle Database Release 23ai JDBC driver supports Application Continuity when Database Resident Connection Pooling (DRCP) is enabled on the server side.

For using Application Continuity with DRCP, you must configure an application service to a server that uses DRCP. The following code snippet shows how to use Application Continuity with DRCP:

Example 33-1 Using Application Continuity with DRCP

```
...
String url = "jdbc:oracle:thin:@(DESCRIPTION =
                          (TRANSPORT_CONNECT_TIMEOUT=3000)
                          (RETRY_COUNT=20)(RETRY_DELAY=3s)(FAILOVER=ON)
                          (ADDRESS_LIST =(ADDRESS=(PROTOCOL=tcp)
                          (HOST=CLOUD-SCANVIP.example.com)(PORT=5221))
                          (CONNECT_DATA=(SERVICE_NAME=ac-service)
(SERVER=POOLED)))";
PoolDataSource pds = PoolDataSourceFactory.getPoolDataSource();
pds.setConnectionFactoryClassName("oracle.jdbc.pool.OracleDataSource");

// Set DataSource Property
pds.setUser("HR");
pds.setPassword("hr");
System.out.println ("Connecting to " + url);
pds.setURL(url);
pds.setConnectionPoolName("HR-Pool1");
pds.setMinPoolSize(2);
pds.setMaxPoolSize(3);
pds.setInitialPoolSize(2);
Properties prop = new Properties();
prop.put("oracle.jdbc.DRCPConnectionClass", "HR-Pool1");
pds.setConnectionProperties(prop);
...
```

Related Topics

- Overview of Database Resident Connection Pooling

Related Topics

- About Configuring Oracle Database for Application Continuity for Java
  You must configure Oracle Database for using Application Continuity for Java.

33.4 Application Continuity Support for XA Data Source

Oracle Database 12*c* Release 2 (12.2.0.1) introduced a new feature that enhances Application Continuity with support for Oracle XA data source (`javax.sql.XADataSource`), which is similar to non-XA data source (`javax.sql.DataSource`). Both JDBC and Java Transaction API (JTA) allow a JDBC connection to interchangeably participate in local and global/XA transactions.

However, many customer applications obtain connections from an XA data source, but use these connections to perform only local transactions. With the new feature, Application Continuity also covers applications that are using XA-capable data sources but with local

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transactions, including local transactions that are promotable to global/XA transactions. So, the benefits of Application Continuity, such as, failover and forward-recovery are extended to these applications.

> **Note**
>
> You must use Transaction Guard 12.2 or later for using this feature.

Whenever an underlying physical connection participates in a global/XA transaction, or engages in any XA operation, replay is disabled on that connection. All other XA operations function normally, but the application does not get Application Continuity protection.

Once replay is disabled on a connection for the above reasons, it remains disabled until the next request begins. Switching from global/XA transaction to local transaction mode does not automatically re-enable replay on a connection.

To use the XA data source with the local transaction feature, you must specify an Oracle JDBC driver XA data source, similar to the regular Application Continuity configuration (non-XA). The XA data source also depends on the Oracle JDBC driver version that you use, so:

- If you use Oracle JDBC driver 23ai, then you should use `oracle.jdbc.replay.OracleXADataSourceImpl`, although the older `oracle.jdbc.xa.client.OracleXADataSource` also works.
- If you use Oracle JDBC driver 19c or older, then you must use `oracle.jdbc.replay.OracleXADataSourceImpl`.

The following code snippet illustrates how replay is supported for local transactions, and disabled for XA transaction, when the connections are obtained from `OracleXADataSource`:

```
import javax.transaction.xa.*;
import oracle.jdbc.replay.OracleXADataSource;
import oracle.jdbc.replay.OracleXADataSourceFactory;
import oracle.jdbc.replay.ReplayableConnection;

OracleXADataSource xards = OracleXADataSourceFactory.getOracleXADataSource();
xards.setURL(connectURL);
xards.setUser(<user_name>);
xards.setPassword(<password>);
XAConnection xaconn = xards.getXAConnection();

// Implicit request begins
Connection conn = xaconn.getConnection();


/* Local transaction case */
// Request-boundary detection OFF
((ReplayableConnection) conn).beginRequest();
conn.setAutoCommit(false);
PreparedStatement pstmt=conn.prepareStatement(“select
cust_first_name,cust_last_name from customers where customer_id=1");
ResultSet rs=pstmt.executeQuery();

// Outage happens at this point
// Replay happens at this point
rs.next();
```


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```
rs.close();
pstmt.close();
((ReplayableConnection) conn).endRequest();
...

/* Global/XA transaction case */
((ReplayableConnection) conn).beginRequest();
conn.setAutoCommit(false);
XAResource xares = xaconn.getXAResource();
Xid xid = createXid();

// Replay is disabled here
xares.start(xid, XAResource.TMNOFLAGS);
conn.prepareStatement("INSERT INTO TEST_TAB VALUES(200, 'another new
record')");

// outage happens at this point
try {

//No replay here and throws exception
conn.executeUpdate();
}

// sqlrexc.getNextException() shows the reason for the replay failure
catch (SQLRecoverableException sqlrexc) {

    ….....
}
```

33.5 About Identifying Request Boundaries in Application Continuity for Java

A Request is a unit of work on a physical connection to Oracle Database that is protected by Application Continuity. Request demarcation varies with specific use-case scenarios. A request begins when a connection is borrowed from the Universal Connection Pool (UCP) or WebLogic Server connection pool, and ends when this connection is returned to the connection pool.

The JDBC driver provides explicit request boundary declaration APIs `beginRequest` and `endRequest` in the `oracle.jdbc.OracleConnection` interface. These APIs enable applications, frameworks, and connection pools to indicate to the JDBC Replay Data Source about demarcation points, where it is safe to release the call history, and to enable replay if it had been disabled by a prior request. At the end of the request, the JDBC Replay Data Source purges the recorded history on the connection, where the API is called. This helps to further conserve memory consumption for applications that use the same connections for an extended period of time without returning them to the pool.

For the connection pool to work, the application must get connections when needed, and release connections when not in use. This scales better and provides request boundaries transparently. The APIs have no impact on the applications other than improving resource consumption, recovery, and load balancing performance. These APIs do not involve altering a connection state by calling any JDBC method, SQL, or PL/SQL. An error is returned if an attempt is made to begin or end a request while a local transaction is open.

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33.6 Support for Transparent Application Continuity

Oracle Database Release 18c introduced the Transparent Application Continuity feature, which is a functional mode of Application Continuity. Transparent Application Continuity transparently tracks and records session and transactional state, so that a database session can be recovered following recoverable outages. This is performed safely and without the need for any knowledge of the application or application code changes. Transparency is achieved by using a state-tracking infrastructure that categorizes session state usage as an application issues user calls. This feature enables the driver to detect and inject possible request boundaries, which are known as implicit request boundaries. For an implicit request boundary:

- No objects are open
- Cursors are returned to the driver statement cache
- No transactions are open

The session state in such a case is known to be restorable. The driver either closes the current capture and starts a new event, or enables capture if there had been a disabling event. On the next call to the server, the server verifies and, if applicable, creates a request boundary, where there was previously no explicit boundary.

To use Transparent Application Continuity, you must set the server-side service attribute `FAILOVER_TYPE` on the database service to `AUTO`.

Support for implicit request helps to reduce application failover recovery time and optimizes Application Continuity. Using Transparent Application Continuity, the server and the drivers can track transaction and session state usage. However, this feature should be used with caution for applications that change server session states during a request. The JDBC Thin driver provides the `oracle.jdbc.enableImplicitRequests` property to turn off implicit requests, if needed. This property can be set at the system level, which applies to all connections, or at the connection level, which applies to a particular connection. By default, the value of this property is `true`, which means that support for implicit request is enabled.

> **See Also**
>
> *Oracle Real Application Clusters Administration and Deployment Guide*

Starting from Oracle Database Release 19c, if you set the value of the `FAILOVER_TYPE` service attribute to `AUTO`, then the Oracle JDBC driver implicitly begins a request on each new physical connection created through the replay data source. With this feature, applications using third-party connection pools can use Transparent Application Continuity (TAC) easily, without making any code change to inject request boundaries.

This implicit `beginRequest` applies only to the replay data source, and only to the physical connections created during runtime, when TAC is enabled. The driver does not implicitly begin a request after each reconnection during replay attempts (that is, a `beginRequest` is not implicitly injected during a replay connection) or in manual Application Continuity mode, where the `FAILOVER_TYPE` service attribute is set to `TRANSACTION`.

If you want to turn off this feature explicitly, you can set the value of the Java system property `oracle.jdbc.beginRequestAtConnectionCreation` to `false`. The default value of this property is `true`.

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Related Topics

- About Enabling FAILOVER_RESTORE
  This section describes how to use the `FAILOVER_RESTORE` service attribute.

33.6.1 Support for Resumable Cursors

Starting from Release 23ai, Oracle JDBC drivers support resumable cursors by default, when using Transparent Application Continuity (TAC). Typically, these cursors are long-running cursors that stay open outside of transactional work. This support increases TAC protection coverage for applications with resumable cursors because it establishes implicit request boundaries more often, even when such cursors are open.

A resumable cursor can remain valid for the entire duration of an explicit request, and can be replayed separately from the main request. Such cursors are commonly used in batch processes. A cursor is considered as a resumable cursor if it meets the following criteria:

- The cursor must be opened when connected to a TAC service
- The cursor must be open when:
  - The session has no open transaction in progress
  - The non-transactional session state is either client restorable or template restorable
- It must be possible to re-execute the query using the system change number (SCN), if replay is required
- The cursor must not create, modify, or read session state during a fetch call, if the fetch call occurs during a round trip that is separate from the cursor execution call

Basically, session state referenced by the cursor must be frozen at the conclusion of the execution phase. Some examples of cursors that are generally not classified as resumable cursors are the cursors that reference the following:

- `sequence.nextval`, `sequence.currval`
- `sys_context` or application context
- PL/SQL functions

> **Note**
>
> The preceding references are still disqualifying if they occur during fetch-time as a result of VPD-imposed clauses.

> **See Also**
>
> *Real Application Clusters Administration and Deployment Guide*

33.7 Establishing the Initial State Before Application Continuity Replays

Non-transactional session state (NTSS) is state of a database session that exists outside database transactions and is not protected by recovery. For applications that use stateful requests, the non-transactional state is re-established as the rebuilt session.

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For applications that set state only at the beginning of a request, or for stateful applications that gain performance benefits from using connections with a preset state, one among the following callback options are provided:

- No Callback
- Connection Labeling
- Connection Initialization Callback
- About Enabling FAILOVER_RESTORE

33.7.1 No Callback

In this scenario, the application builds up its own state during each request.

33.7.2 Connection Labeling

This scenario is applicable only to Universal Connection Pool (UCP) and Oracle WebLogic Server. You can modify the application to take advantage of the preset state on connections. Connection Labeling APIs first determine how well a connection matches, and then use a callback to populate the gap when a connection is borrowed.

> **Note**
>
> If you are using connection labeling, then you cannot set the `RESET_STATE` service attribute to `LEVEL1` or `LEVEL2`.

> **See Also**
>
> *Oracle Universal Connection Pool Developer's Guide*

33.7.3 Connection Initialization Callback

In this scenario, the replay data source uses an application callback to set the initial state of the session during runtime and replay. The JDBC Replay Data Source provides an optional connection initialization callback interface as well as methods for registering and unregistering such callbacks.

When registered, the initialization callback is executed at each successful reconnection following a recoverable error. An application is responsible for ensuring that the initialization actions are the same as that on the original connection before failover. If the callback invocation fails, then replay is disabled on that connection.

This section discusses initialization callbacks in the following sections:

- Creating an Initialization Callback
- Registering an Initialization Callback
- Removing or Unregistering an Initialization Callback

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33.7.3.1 Creating an Initialization Callback

To create a JDBC connection initialization callback, an application implements the `oracle.jdbc.replay.ConnectionInitializationCallback` interface. One callback is allowed for every instance of the `oracle.jdbc.replay.OracleDataSource` interface.

> **Note**
>
> This callback is only invoked during failover, after a successful reconnection.

Example

The following code snippet demonstrates a simple initialization callback implementation:

```
import oracle.jdbc.replay.ConnectionInitializationCallback;
class MyConnectionInitializationCallback implements ConnectionInitializationCallback
{
    public MyConnectionInitializationCallback()
    {
        ...
    }
    public void initialize(java.sql.Connection connection) throws SQLException
    {
        // Reset the state for the connection, if necessary (like ALTER SESSION)
        ...
    }
 }
```

For applications using an XA data source, the connection initialization callback is registered on the XA replay data source. The callback is executed every time when *both* of the following happen:

- A connection is borrowed from the connection pool.
- The replay XA data source gets a new physical connection at failover.

> **Note**
>
> The connection initialization must be idempotent. If the connection is already initialized, then it must not repeat itself. This enables applications to reestablish session initial starting point after a failover and before the starting of replay. The callback execution must leave an open local transaction without committing it or rolling it back. If this is violated, an exception is thrown.

If a callback invocation fails, replay is disabled on that connection. For example, an application embeds the set up phase for a connection in this callback.

33.7.3.2 Registering an Initialization Callback

Use the following method that the JDBC Replay Data Source provides in the `oracle.jdbc.replay.OracleDataSource` interface for registering a connection initialization callback:

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```
registerConnectionInitializationCallback(ConnectionInitializationCallback cbk)
```

One callback is allowed for every instance of the `OracleDataSource` interface.

For using an XA Data Source, use the `registerConnectionInitializationCallback(ConnectionInitializationCallback cbk)` method in the `oracle.jdbc.replay.OracleXADataSource` interface.

33.7.3.3 Removing or Unregistering an Initialization Callback

Use the following method that the JDBC Replay Data Source provides in the `oracle.jdbc.replay.OracleDataSource` interface for unregistering a connection initialization callback:

```
unregisterConnectionInitializationCallback(ConnectionInitializationCallback cbk)
```

For using an XA Data Source, use the `unregisterConnectionInitializationCallback(ConnectionInitializationCallback cbk)` method in the `oracle.jdbc.replay.OracleXADataSource` interface.

33.7.4 About Enabling FAILOVER_RESTORE

This section describes how to use the `FAILOVER_RESTORE` service attribute.

`FAILOVER_RESTORE` service attribute was introduced in Oracle Database 12*c* Release 2 (12.2.0.1). Setting the `FAILOVER_RESTORE` attribute to `LEVEL1` automatically restores the common initial state before replaying a request. By default, the value of the `FAILOVER_RESTORE` attribute is set to `NONE`, which means that it is disabled.

Starting from Oracle Database Release 18c, you can also set the value of this attribute to `AUTO`. Also, if you set the value of the `FAILOVER_TYPE` attribute to `AUTO`, then `FAILOVER_RESTORE` is set to `AUTO` automatically. You cannot change the value of `FAILOVER_RESTORE` to anything else as long as `FAILOVER_TYPE` is set to `AUTO`. When `FAILOVER_RESTORE` is set to `AUTO`, then the common initial state is also set. As far as session state restore is concerned, this setting provides the same function as `FAILOVER_RESTORE` set to `LEVEL1`.

> **See Also**
>
> *Real Application Clusters Administration and Deployment Guide*

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Note

For Application Continuity for Java available with Oracle Database Release 23ai, the following initial states are supported for `FAILOVER_RESTORE`:

- `NLS_CALENDAR`
- `NLS_CURRENCY`
- `NLS_DATE_FORMAT`
- `NLS_DATE_LANGUAGE`
- `NLS_DUAL_CURRENCY`
- `NLS_ISO_CURRENCY`
- `NLS_LANGUAGE`
- `NLS_LENGTH_SEMANTICS`
- `NLS_NCHAR_CONV_EXCP`
- `NLS_NUMERIC_CHARACTER`
- `NLS_SORT`
- `NLS_TERRITORY`
- `NLS_TIME_FORMAT`
- `NLS_TIME_TZ_FORMAT`
- `NLS_TIMESTAMP_FORMAT`
- `NLS_TIMESTAMP_TZ_FORMAT`
- `TIME_ZONE (OCI, ODP.NET 12201)`
- `CURRENT_SCHEMA`
- `MODULE`
- `ACTION`
- `CLIENT_ID`
- `ECONTEXT_ID`
- `ECONTEXT_SEQ`
- `DB_OP`
- `AUTOCOMMIT` states (Java and SQL*Plus)
- `CONTAINER` (PDB) and `SERVICE` for OCI and ODP.NET

Starting from Oracle Database Release 19c, the following additional initial states are supported for `FAILOVER_RESTORE`:

- `ERROR_ON_OVERLAP_TIME`
- `EDITION`
- `SQL_TRANSLATION_PROFILE`
- `ROW ARCHIVAL VISIBILITY`
- `ROLEs`
- `CLIENT_INFO`

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> **Note**
>
> Since Oracle Database Release 19c, `FAILOVER_RESTORE` is automatically enabled in Transparent Application Continuity (TAC) mode.

The following states are excluded from the auto-restoration option because they are not supported by the Thin driver:

- `NLS_COMP`
- `CALL_COLLECT_TIME`

For many applications, enabling `FAILOVER_RESTORE` is sufficient to automatically restore the initial state required for AC replay, without the use of a callback. If your application requires any initial state that is not mentioned in the preceding list, or if the application prefers explicit control over setting the initial state, then the application must use a callback, either connection labeling or an initialization callback. When a callback is configured, it overrides the initial states restored by `FAILOVER_RESTORE`, in case the latter is enabled at the same time.

33.8 About Delaying the Reconnection in Application Continuity for Java

By default, when JDBC Replay Data Source initiates a failover, the driver attempts to recover the in-flight work at an instance where the service is available. For doing this, the driver must first reestablish a good connection to a working instance. This reconnection can take some time if the database or the instance needs to be restarted before the service is relocated and published. So, the failover should be delayed until the service is available from another instance or database.

You must use the `FAILOVER_RETRIES` and `FAILOVER_DELAY` parameters to sustain the delay because maximum delay is calculated as `FAILOVER_RETRIES` multiplied by `FAILOVER_DELAY`. These parameters can work well in conjunction with a planned outage, for example, an outage that may make a service unavailable for several minutes. While setting the `FAILOVER_DELAY` and `FAILOVER_RETRIES` parameters, check the value of the `REPLAY_INITIAITION_TIMEOUT` parameter first. The default value for this parameter is 900 seconds. A high value for the `FAILOVER_DELAY` parameter can cause replay to be canceled.

Parameter Name	Possible Value	Default Value
`FAILOVER_RETRIES`	Positive integer zero or above	30
`FAILOVER_DELAY`	Time in seconds	10

33.8.1 Configuration Examples Related to Application Continuity for Java

This section provides configuration examples for service creation and modification in the following subsections:

- Creating Services on Oracle RAC
- Modifying Services on Single-Instance Databases

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33.8.1.1 Creating Services on Oracle RAC

If you are using Oracle RAC or Oracle RAC One, then use the `SRVCTL` command to create and modify services in the following way:

For Transparent Application Continuity

You can create services that use Transparent Application Continuity, as follows:

For policy-managed databases:

```
$ srvctl add service -db codedb -service GOLD -serverpool ora.Srvpool -
clbgoal SHORT -rlbgoal SERVICE_TIME -failover_restore AUTO -failoverretry 30
-failoverdelay 10 -commit_outcome TRUE -failovertype AUTO -replay_init_time
1800 -retention 86400  -notification TRUE
```

For administrator-managed databases:

```
$ srvctl add service -db codedb -service GOLD -preferred serv1 -available
serv2 -clbgoal SHORT -rlbgoal SERVICE_TIME -failover_restore AUTO
-failoverretry 30 -failoverdelay 10 -commit_outcome TRUE -failovertype AUTO -
replay_init_time 1800 -retention 86400 -notification TRUE
```

For Manual Application Continuity

You can create services that use manual Application Continuity, as follows:

For policy-managed databases:

```
$ srvctl add service -db codedb -service GOLD -serverpool ora.Srvpool -
clbgoal SHORT -rlbgoal SERVICE_TIME -failover_restore LEVEL1 -failoverretry
30
-failoverdelay 10 -commit_outcome TRUE -failovertype TRANSACTION -
replay_init_time 1800 -retention 86400 -notification TRUE
```

For administrator-managed databases:

```
$ srvctl add service -db codedb -service GOLD -preferred serv1 -available
serv2 -clbgoal SHORT -rlbgoal SERVICE_TIME -failover_restore LEVEL1
-failoverretry 30 -failoverdelay 10 -commit_outcome TRUE -failovertype
TRANSACTION -replay_init_time 1800 -retention 86400 -notification TRUE
```

33.8.1.2 Modifying Services on Single-Instance Databases

If you are using a single-instance database, then use the `DBMS_SERVICE` package to modify services in the following way:

```
declare
params dbms_service.svc_parameter_array;
begin
params('FAILOVER_TYPE'):='TRANSACTION';
params('REPLAY_INITIATION_TIMEOUT'):=1800;
params('RETENTION_TIMEOUT'):=604800;
params('FAILOVER_DELAY'):=10;
```


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```
params('FAILOVER_RETRIES'):=30;
params('commit_outcome'):='true';
params('aq_ha_notifications'):='true';
dbms_service.modify_service('[your service]',params);
end;
/
```

33.9 About Retaining Mutable Values in Application Continuity for Java

A mutable object is a variable, function return value, or other structure that returns a different value each time that it is called. For example, `Sequence.NextVal`, `SYSDATE`, `SYSTIMESTAMP`, and `SYS_GUID`. To retain the function results for named functions at replay, the DBA must grant `KEEP` privileges to the user who invokes the function. This security restriction is imposed to ensure that it is valid for replay to save and restore function results for code that is not owned by that user.

> **See Also**
>
> *Oracle Database Development Guide*

33.9.1 Grant and Revoke Interface

You can work with mutables values by using the standard `GRANT` and `REVOKE` interfaces in the following way:

- Dates and SYS_GUID Syntax
- Sequence Syntax
- GRANT ALL Statement
- Rules for Grants on Mutable Values

33.9.1.1 Dates and SYS_GUID Syntax

The `DATE_TIME` and `SYS_GUID` syntax is as follows:

```
GRANT [KEEP DATE TIME|SYSGUID]..[to USER}
REVOKE [KEEP DATE TIME | KEEP SYSGUID] … [from USER]
```

For example, for EBS standard usage with original dates

```
Grant KEEP DATE TIME,  KEEP SYSGUID  to [custom user];
Grant KEEP DATE TIME,  KEEP SYSGUID  to [apps user];
```

33.9.1.2 Sequence Syntax

The Sequence syntax can be of the following types:

- Owned Sequence Syntax
- Others Sequence Syntax

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Owned Sequence Syntax

```
ALTER SEQUENCE [sequence object] [KEEP|NOKEEP];
```

This command retains the original values of `sequence.nextval` for replaying, so that the keys match after replay. Most applications need to retain the sequence values at replay. The `ALTER SYNTAX` is only for owned sequences.

Others Sequence Syntax

```
GRANT KEEP SEQUENCE..[to USER] on [sequence object];
REVOKE  KEEP SEQUENCE … [from USER]  on [sequence object];
```

For example, use the following command for EBS standard usage with original sequence values:

```
Grant KEEP SEQUENCE  to [apps user] on [sequence object];
Grant KEEP SEQUENCE  to [custom user] on [sequence object];
```

33.9.1.3 GRANT ALL Statement

The `GRANT ALL` statement grants `KEEP` privilege on all the objects of a user. However, it excludes mutable values, that is, mutable values require explicit grants.

33.9.1.4 Rules for Grants on Mutable Values

Follow these rules while granting privileges on mutable objects:

- If a user has `KEEP` privilege granted on mutables values, then the objects inherit mutable access when the `SYS_GUID`, `SYSDATE`, and `SYSTIMESTAMP` functions are called.
- If the `KEEP` privilege on mutable values on a sequence object is revoked, then SQL or PL/SQL blocks using that object will not allow mutable collection or application for that sequence.
- If granted privileges are revoked between runtime and failover, then the mutable values that are collected are not applied for replay.
- If new privileges are granted between runtime and failover, mutable values are not collected and these values are not applied for replay.

33.10 Application Continuity Statistics

The JDBC Replay Data Source supports the following statistics for an application using Application Continuity:

- Total number of requests
- Total number of completed requests
- Total number of calls
- Total number of protected calls
- Total number of calls affected by outages
- Total number of calls triggering replay
- Total number of calls affected by outages during replay

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- Total number of successful replay
- Total number of failed replay
- Total number of disabled replay
- Total number of replay attempts

All these metrics are available both on a per-connection basis and across-connections basis. You can use the following methods for obtaining these statistics:

- `getReplayStatistics(StatisticsReportType)`

  Use the `oracle.jdbc.replay.ReplayableConnection.getReplayStatistics(StatisticsReportType)` method to obtain the snapshot statistics. The argument to this method is an enum type also defined in the same `ReplayableConnection` interface. To obtain statistics across connections, it is best calling this method after the main application logic. Applications can either use any `oracle.jdbc.replay.ReplayableConnection` that is still open, or open a new connection to the same data source. This applies to applications using both UCP and WLS data sources, and applications that directly use the replay data source.

- `getReplayStatistics()`

  Use the `oracle.jdbc.replay.OracleDataSource.getReplayStatistics()` method to obtain across-connection statistics. This applies only to applications that directly use replay data source.

Both methods return an `oracle.jdbc.replay.ReplayStatistics` object, from which you can retrieve individual replay metrics. The following is a sample output that prints a ReplayStatistics object as String:

```
AC Statistics:
=============================================
TotalRequests = 1
TotalCompletedRequests = 1
TotalCalls = 19
TotalProtectedCalls = 19
=============================================
TotalCallsAffectedByOutages = 3
TotalCallsTriggeringReplay = 3
TotalCallsAffectedByOutagesDuringReplay = 0
=============================================
SuccessfulReplayCount = 3
FailedReplayCount = 0
ReplayDisablingCount = 0
TotalReplayAttempts = 3
=============================================
```

If you want to clear the accumulated replay statistics per connection or for all connections, then you can use the following methods:

- `oracle.jdbc.replay.ReplayableConnection.clearReplayStatistics(ReplayableConnection.StatisticsReportType reportType)`
- `oracle.jdbc.replay.OracleDataSource.clearReplayStatistics()`

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> **Note**
>
> All statistics reflect only updates since the latest clearing.

33.11 About Disabling Replay in Application Continuity for Java

This section describes the following concepts:

- How to Disable Replay
- When to Disable Replay
- Diagnostics and Tracing

33.11.1 How to Disable Replay

If any application module uses a design that is unsuitable for replay, then the disable replay API disables replay on a per request basis. Disabling replay can be added to the callback or to the main code by using the `disableReplay` method of the `oracle.jdbc.replay.ReplayableConnection` interface. For example:

```
if (connection instanceof oracle.jdbc.replay.ReplayableConnection)
{
    (( oracle.jdbc.replay.ReplayableConnection)connection).disableReplay();

}
```

Disabling replay does not alter the connection state by reexecuting any JDBC method, SQL or PL/SQL. When replay is disabled using the disable replay API, both recording and replay are disabled until that request ends. There is no API to reenable replay because it is invalid to reestablish the database session with time gaps in a replayed request. This ensures that replay runs *only* if a complete history of needed calls has been recorded.

33.11.2 When to Disable Replay

By default, the JDBC Replay Data Source replays following a recoverable error. The disable replay API can be used in the entry point of application modules that are unable to lose the database sessions and recover. For example, if the application uses the `UTL_SMTP` package and does not want messages to be repeated, then the `disableReplay` API affects only the request that needs to be disabled. All other requests continue to be replayed.

The following are scenarios to consider before configuring an application for replay:

- Application Calls External PL/SQL Actions that Should not Be Repeated
- Application Synchronizes Independent Sessions
- Application Uses Time at the Middle-tier in the Execution Logic
- Application assumes that ROWIds do not change
- Application Assumes that Side Effects Execute Once
- Application Assumes that Location Values Do not Change

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33.11.2.1 Application Calls External Systems that Should not Be Repeated

During replay, autonomous transactions and external systems (like PL/SQL calls or Java calls) can have side effects that are separate from the main transaction. These side effects are replayed unless you specify otherwise and leave persistent results behind. These side effects include writing to an external table, sending email, forking sessions out of PL/SQL or Java, transferring files, accessing external URLs, and so on. For example, in case of PL/SQL messaging, suppose, you walk away in-between some work without committing and the session times out. Now, if you issue a `Ctrl+C` command, then the foreground of a component fails. When you resubmit the work, then this side effect can also be repeated.

> **See Also**
>
> *Oracle Real Application Clusters Administration and Deployment Guide* for more information about potential side effects of Application Continuity

You must make a conscious decision about whether to enable replay for external actions or not. For example, you can consider the following situations where this decision is important:

- Using the `UTL_HTTP` package to issue a SOA call
- Using the `UTL_SMTP` package to send a message
- Using the `UTL_URL` package to access a web site

Use the `disableReplay` API if you do not want such external actions to be replayed.

33.11.2.2 Application Synchronizes Independent Sessions

You can configure an application for replay if the application synchronizes independent sessions using volatile entities that are held until commit, rollback, or session loss. In this case, the application synchronizes multiple sessions connected to several data sources that are otherwise inter-dependent using resources such as a database lock. This synchronization may be fine if the application is only serializing these sessions and understands that any session may fail. However, if the application assumes that a lock or any other volatile resource held by one data source implies exclusive access to data on the same or a separate data source from other connections, then this assumption may be invalidated when replaying.

During replay, the driver is not aware that the sessions are dependent on one session holding a lock or other volatile resource. You can also use pipes, buffered queues, stored procedures taking a resource (such as a semaphore, device, or socket) to implement the synchronization that are lost by failures.

> **Note**
>
> The `DBMS_LOCK` does not replay in the restricted version.

33.11.2.3 Application Uses Time at the Middle-tier in the Execution Logic

In this case, the application uses the wall clock at the middle-tier as part of the execution logic. The JDBC Replay Data Source does not repeat the middle-tier time logic, but uses the database calls that execute as part of this logic. For example, an application using middle-tier

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time may assume that a statement executed at Time T1 is not reexecuted at Time T2, unless the application explicitly does so.

33.11.2.4 Application assumes that ROWIds do not change

If an application caches ROWIDs, then access to these ROWIDs may be invalidated due to database changes. Although a ROWID uniquely identifies a row in a table, a ROWID may change its value in the following situations:

- The underlying table is reorganized
- An index is created on the table
- The underlying table is partitioned
- The underlying table is migrated
- The underlying table is exported and imported using EXP/IMP/DUL
- The underlying table is rebuilt using Golden Gate or Logical Standby or other replication technology
- The database of the underlying table is flashed back or restored

It is bad practice for an application to store ROWIDs for later use as the corresponding row may either not exist or contain completely different data.

33.11.2.5 Application Assumes that Side Effects Execute Once

In this case, the following are replayed during a replay:

- Autonomous transactions
- Opening of back channels separate to the main transaction side effects

Examples of back channels separate to the main transaction include writing to an external table, sending email, forking sessions out of PL/SQL or Java, writing to output files, transferring files, and writing exception files. Any of these actions leave persistent side effects in the absence of replay. Back channels can leave persistent results behind. For example, if a user leaves a transaction midway without committing and the session times out, then the user presses Ctrl+C, the foreground or any component fails. If the user resubmits work, then the side effects can be repeated.

33.11.2.6 Application Assumes that Location Values Do not Change

`SYSCONTEXT` options comprise a location-independent set such as National Language Support (NLS) settings, `ISDBA`, `CLIENT_IDENTIFIER`, `MODULE`, and `ACTION`, and a location-dependent set that uses physical locators. Typically, an application does not use the physical identifier, except in testing environments. If physical locators are used in mainline code, then the replay finds the mismatch and rejects it. However, it is fine to use physical locators in callbacks.

Example

```
select
    sys_context('USERENV','DB_NAME')
    ,sys_context('USERENV','HOST')
    ,sys_context('USERENV','INSTANCE')
    ,sys_context('USERENV','IP_ADDRESS')
    ,sys_context('USERENV','ISDBA')
    ,sys_context('USERENV','SESSIONID')
    ,sys_context('USERENV','TERMINAL')
```


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```
    ,sys_context('USERENV',ID')
from dual
```

33.11.3 Diagnostics and Tracing

The JDBC Replay Data Source supports standard JDK logging. Logging is enabled using the Java command-line `-Djava.util.logging.config.file=<file>` option. Log level is controlled with the `oracle.jdbc.level` attribute in the log configuration file. For example:

```
oracle.jdbc.level = FINER|FINEST
```

where, `FINER` produces external APIs and `FINEST` produces large volumes of trace. You must use `FINEST` only under supervision.

If you use the `java.util.logging.XMLFormatter` class to format a log record, then the logs are more readable but larger. If you are using replay with FAN enabled on UCP or WebLogic Server, then you should also enable FAN-processing logging.

See Also

- Diagnosability in JDBC
- *Oracle Universal Connection Pool for JDBC Developer's Guide*

33.11.3.1 Writing Replay Trace to Console

Following is the example of a configuration file for logging configuration.

```
oracle.jdbc.level = FINER
handlers = java.util.logging.ConsoleHandler
java.util.logging.ConsoleHandler.level = ALL
java.util.logging.ConsoleHandler.formatter = java.util.logging.XMLFormatter
```

33.11.3.2 Writing Replay Trace to a File

Following is the example of a `properties` file for logging configuration.

```
oracle.jdbc.level = FINEST

# Output File Format (size, number and style)
# count: Number of output files to cycle through, by appending an integer to the base
file name:
# limit: Limiting size of output file in bytes
handlers = java.util.logging.FileHandler
java.util.logging.FileHandler.pattern = [file location]/replay_%U.trc
java.util.logging.FileHandler.limit = 500000000
java.util.logging.FileHandler.count = 1000
java.util.logging.FileHandler.formatter = java.util.logging.XMLFormatter
```

See Also

Restrictions and Other Considerations for Application Continuity

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34

Oracle JDBC Support for FAN Events

Starting from Oracle Database 12*c* Release 2 (12.2.0.1), Oracle JDBC driver supports Oracle RAC Fast Application Notification (FAN) events, for planned and unplanned outages. This facilitates third-party connection pools to leverage Oracle RAC features for high availability. Java applications not using Oracle Universal Connection Pool (UCP) or WebLogic Server can now leverage on this support. For example, scenarios like rolling upgrades at the Oracle RAC server-side do not cause JDBC errors within applications.

> **Note**
>
> Although the Oracle JDBC drivers now support the FAN events, Oracle UCP provides more comprehensive support for all FAN events.

> **See Also**
>
> *Oracle Universal Connection Pool Developer's Guide*

- Overview of Oracle JDBC Support for FAN events
- Safe Draining APIs for Planned Maintenance
- Installation and Configuration of Oracle JDBC Driver for FAN Events Support
- Example of Oracle JDBC Driver FAN support for Planned Maintenance
- Using Third-Party Connection Pools with Oracle JDBC

34.1 Overview of Oracle JDBC Support for FAN events

You must use an Oracle RAC Database or an Oracle Restart on a single instance database to use this feature.

This feature supports:

- Planned maintenance

  This case deals with planned maintenance on Oracle RAC servers, where an Oracle RAC service can be gracefully shutdown. In this case, borrowed or in-use connections from a connection pool are not interrupted, and are closed only until any safe-draining API is invoked. For example, when an application completes work on such a connection and returns it to the connection pool.

- Unplanned outages

  In this case, dead connections are rapidly detected and terminated, so that the network connections to the server do not become nonresponsive.. In this case, borrowed and in-use connections are interrupted during unplanned outages. Applications are expected to handle any exception on affected connections and perform necessary recovery, either on their own, or using Oracle high-availability solutions such as Application Continuity.

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Related Topics

- Application Continuity for Java
  The outages of the underlying software, hardware, communications, and storage layers can cause application execution to fail. In the worst cases, the middle-tier servers may need to be restarted to deal with a logon storm, which is a sudden increase in the number of client connection requests.

Related Topics

- Safe Draining APIs for Planned Maintenance

> **See Also**
>
> *Oracle Real Application Clusters Administration and Deployment Guide*for server-side configuration about using Oracle RAC. This chapter describes only the client-side configuration steps that an application must perform when using Oracle JDBC driver support for FAN events.

34.2 Safe Draining APIs for Planned Maintenance

For planned Oracle RAC maintenance, the JDBC driver supports a list of safe-draining APIs, which are required for additional handshake or integration work with a third-party Java connection pool. These APIs serve as the *draining-points*, where the driver can safely close any connection affected by a planned maintenance, without causing application-visible errors. Following is the list of safe-draining APIs that driver FAN supports:

- `java.sql.Connection.isValid(int timeout)`
- `oracle.jdbc.OracleConnection.pingDatabase()`
- `oracle.jdbc.OracleConnection.pingDatabase(int timeout)`
- `oracle.jdbc.OracleConnection.endRequest()`
- All standard JDBC and Oracle JDBC extension `EXECUTE***` calls on `Statement`, `PreparedStatement`, and `CallableStatement` interfaces

For the standard JDBC and Oracle JDBC extension `EXECUTE***` calls, the executed SQL command string must contain the following SQL hint as the first noncomment token within the SQL string:

```
/*+ CLIENT_CONNECTION_VALIDATION */
```

Qualified SQLs are treated as connection-validation SQLs. For example:

```
/*+ CLIENT_CONNECTION_VALIDATION */ SELECT 1 FROM DUAL
```

Typically, a third-party connection pool places calls to these APIs. It is expected that on detection of any bad connection with such invocations, a third-party connection pool closes and removes the related connection from the pool, so that no errors are visible to applications. When the application itself calls these APIs, then it is expected that application is actively validating the underlying connection and will close and remove any bad connection detected.

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34.3 Installation and Configuration of Oracle JDBC Driver for FAN Events Support

Oracle JDBC driver automatically determines whether to enable Oracle JDBC support for FAN events, by checking the database server that it connects to, and whether the following necessary JAR files are available in the application environment, in addition to the Oracle JDBC driver or not:

- The `simplefan.jar` and `ons.jar` files

  You must install the `simplefan.jar` and `ons.jar` files from the JDBC and UCP Downloads page and include them in the `CLASSPATH`.

  If either one is missing, or the driver is unable to load it, then this feature is disabled. When used with a third-party connection pool, these JAR files must be placed in the same location, where the connection pool retrieves and loads the driver JAR files.

- Oracle JDBC data sources

  You can use the same typical Oracle JDBC data sources, such as `oracle.jdbc.pool.OracleDataSource` or `oracle.jdbc.OracleDriver` for obtaining JDBC connections. When used together with a third-party connection pool, your application must specify these classes as connection factories for the connection pool.

Applications that want to explicitly disable this feature, can set the `oracle.jdbc.fanEnabled` property to `FALSE`. This property is available as both a system property and a connection property. For applications using Universal Connection Pool (UCP) or WebLogic Server Active GridLink (AGL), this property is set to `FALSE` by default. Otherwise, the default value is `TRUE`.

> **Note**
>
> - When the JDBC driver automatically enables support for FAN events, with both the `simplefan.jar` and the `ons.jar` files present on the `CLASSPATH`, then calling the `getConnection` method may throw an exception, such as, `java.lang.IllegalArgumentException`. To avoid this, you can perform either of the following:
>   - Remove either `simplefan.jar` or `ons.jar` from the `CLASSPATH`.
>   - Set the `oracle.jdbc.fanEnabled` property to `FALSE` to disable this feature explicitly.
> - Setting the `oracle.jdbc.fanEnabled` property to `TRUE` may not enable Oracle JDBC Support for FAN Events feature as the feature depends on other factors too.

The JDBC driver requires minimal configuration changes or code changes to a third-party connection pool for supporting Oracle FAN events. For a connection pool that does not need any configuration change or code change, it is assumed that it fulfills one of the following criteria:

- The pool has a configuration option for validating JDBC connections at pool checkout time.
- The pool uses `javax.sql.PooledConnection` and has a configuration option for plugging in a `javax.sql.ConnectionPoolDataSource` implementation. Such a connection pool is also assumed to be able to check for closed or bad physical connections at connection returns.

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Following are a few connection validation options on some third-party Java connection pools. The majority of these options are based on SQL, and not on validation APIs:

Java Connection Pool	Connection Validation Options
Oracle WebLogic Generic and MDS data sources	`TestConnectionsOnReserve`, `TestConnectionsOnRelease`, `TestConnectionsOnCreate`
IBM WebSphere	`PreTest` Connection
RedHat JBoss	`check-valid-connection-sql`
Apache TomCat	`TestonBorrow`, `TestonRelease`

When you use Oracle JDBC support for FAN events feature with an Oracle RAC server Release 11*g*, then applications must explicitly set the remote ONS configuration string for Oracle RAC FAN through the `oracle.jdbc.fanONSConfig` system property. The value and the format of the property are the same as for UCP Fast Connection Failover (FCF).

See Also

Universal Connection Pool Developer's Guide

34.4 Example of Oracle JDBC Driver FAN support for Planned Maintenance

The section discusses how you can typically enable and use JDBC Oracle FAN support with planned maintenance on Oracle RAC.

Applications should not receive any exception during a planned maintenance after following these instructions:

1. Upgrade Oracle JDBC driver to Release 23ai to use the `ojdbc11.jar` or `ojdbc17.jar` file.
2. Install and use the 23ai version of the `ons.jar` and `simplefan.jar` files.
3. Use the `oracle.jdbc.pool.OracleDataSource` class to obtain physical connections or configure this class as the connection factory on a third-party Java connection pool. In the latter case, you must set the specific pool property that enables connection validation.

   Optionally, when running against Oracle RAC Release 21c, specify the system property `oracle.jdbc.fanONSConfig` to configure remote ONS.
4. The application runs until you are ready to perform planned maintenance activities like a rolling upgrade on the Oracle RAC. During the planned maintenance, for each service based on usage patterns, a DBA will perform the following activities using the extended `srvctl` interface:
   - Relocate or stop the services on the next instance to upgrade, with no `-f` (force)
   - Wait until all connections to this service are drained by driver FAN
   - When the timeout is reached, disconnect the sessions with the defined stop mode (transactional is recommended)
   - When all services are relocated or stopped, shutdown the instance and apply the upgrade or patch

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- Restart the instance and restart the services if they were stopped
- Iterate until all instances are upgraded/patched

34.5 Using Third-Party Connection Pools with Oracle JDBC

This section lists the requirements to configure third-party connection pools for supporting planned and unplanned outages.

For configuring the third-party connection pools, ensure that you:

- Enable High Availability (HA) support in the driver
- Enforce connection validation while borrowing the connection
- Tune the connection validation technique to limit the cost
- Enable statement caching in the driver

With the preceding settings, the connections in the third-party connection pools use the draining APIs during a planned down event, for example, when a service is stopped on an instance. For handling unplanned outages, you must also enable Transparent Application Continuity (TAC) on the database service and configure one of the following replay data sources:

- `oracle.jdbc.datasource.impl.OracleDataSource` with Oracle Databases 23ai Release or Oracle Database 21c Release
- `oracle.jdbc.replay.OracleDataSource` with Oracle Database 19c Release

Example

For example, if you want to support planned outages with HikariCP, then you must take care of the following settings:

- Ensure HA support:
  Include the `ons.jar` and `simplefan.jar` files in the classpath
- Ensure connection validation:

  ```
  com.zaxxer.hikari.aliveBypassWindowMs=-1
  ```

- Tune the connection validation technique:

  ```
  oracle.jdbc.defaultConnectionValidation=LOCAL
  ```

- Enable statement caching in the driver:

  ```
  oracle.jdbc.implicitStatementCacheSize=50
  ```


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35
Transparent Application Failover

This chapter contains the following sections:

- Overview of Transparent Application Failover
- Failover Type Events
- TAF Callbacks
- Java TAF Callback Interface
- Comparison of TAF and Fast Connection Failover

35.1 Overview of Transparent Application Failover

Transparent Application Failover (TAF) is a feature of the Java Database Connectivity (JDBC) Oracle Call Interface (OCI) driver. It enables the application to automatically reconnect to a database, if the database instance to which the connection is made fails. In this case, the active transactions roll back.

When an instance to which a connection is established fails or is shut down, the connection on the client-side becomes stale and would throw exceptions to the caller trying to use it. TAF enables the application to transparently reconnect to a preconfigured secondary instance, creating a fresh connection, but identical to the connection that was established on the first original instance. That is, the connection properties are the same as that of the earlier connection. This is true regardless of how the connection was lost.

> **Note**
>
> - TAF is always active and does not have to be set.
> - TAF is not supported with LOB and XML types.

35.2 Failover Type Events

The following are possible failover events in the `OracleOCIFailover` interface:

- `FO_SESSION`

  Is equivalent to `FAILOVER_MODE=SESSION` in the `tnsnames.ora` file `CONNECT_DATA` flags. This means that only the user session is authenticated again on the server side, while open cursors in the OCI application need to be reprocessed.

- `FO_SELECT`

  Is equivalent to `FAILOVER_MODE=SELECT` in `tnsnames.ora` file `CONNECT_DATA` flags. This means that not only the user session is re-authenticated on the server side, but open cursors in the OCI can continue fetching. This implies that the client-side logic maintains fetch-state of each open cursor.

- `FO_NONE`

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Is equivalent to `FAILOVER_MODE=NONE` in the `tnsnames.ora` file `CONNECT_DATA` flags. This is the default, in which no failover functionality is used. This can also be explicitly specified to prevent failover from happening. Additionally, `FO_TYPE_UNKNOWN` implies that a bad failover type was returned from the OCI driver.

- `FO_BEGIN`

  Indicates that failover has detected a lost connection and failover is starting.

- `FO_END`

  Indicates successful completion of failover.

- `FO_ABORT`

  Indicates that failover was unsuccessful and there is no option of retrying.

- `FO_REAUTH`

  Indicates that a user handle has been re-authenticated.

- `FO_ERROR`

  Indicates that failover was temporarily unsuccessful, but it gives the application the opportunity to handle the error and retry failover. The usual method of error handling is to issue the `sleep` method and retry by returning the value `FO_RETRY`.

- `FO_RETRY`

  Indicates that the application should retry failover.

- `FO_EVENT_UNKNOWN`

  Indicates a bad failover event.

35.3 TAF Callbacks

TAF callbacks are used in the event of the failure of one database connection, and failover to another database connection. TAF callbacks are callbacks that are registered in case of failover. The callback is called during the failover to notify the JDBC application of events generated. The application also has some control of failover.

> **Note**
>
> The callback setting is optional.

35.4 Java TAF Callback Interface

The `OracleOCIFailover` interface includes the `callbackFn` method, supporting the following types and events:

```
public interface OracleOCIFailover{

// Possible Failover Types
public static final int FO_SESSION = 1;
public static final int FO_SELECT  = 2;
public static final int FO_NONE  = 3;
public static final int;

// Possible Failover events registered with callback
```


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```
public static final int FO_BEGIN   = 1;
public static final int FO_END     = 2;
public static final int FO_ABORT   = 3;
public static final int FO_REAUTH  = 4;
public static final int FO_ERROR  = 5;
public static final int FO_RETRY  = 6;
public static final int FO_EVENT_UNKNOWN = 7;

public int callbackFn (Connection conn,
                       Object ctxt, // ANy thing the user wants to save
                       int type, // One of the possible Failover Types
                       int event ); // One of the possible Failover Events
```

Handling the FO_ERROR Event

In case of an error while failing over to a new connection, the JDBC application is able to retry failover. Typically, the application sleeps for a while and then it retries, either indefinitely or for a limited amount of time, by having the callback return `FO_RETRY`.

Handling the FO_ABORT Event

Callback registered should return the `FO_ABORT` event if the `FO_ERROR` event is passed to it.

35.5 Comparison of TAF and Fast Connection Failover

Transparent Application Failover (TAF) differs from Fast Connection Failover in the following ways:

- Application-level connection retries

  TAF supports connection retries only at the OCI/Net layer. Fast Connection Failover supports application-level connection retries. This gives the application control of responding to connection failovers. The application can choose whether to retry the connection or to rethrow the exception.

- Integration with the Universal Connection Pool

  TAF works at the network level on a per-connection basis, which means that the connection cache cannot be notified of failures. Fast Connection Failover is well-integrated with the Universal Connection Pool, which enables the Connection Cache Manager to manage the cache for high availability. For example, failed connections are automatically invalidated in the cache.

- Event-based

  Fast Connection Failover is based on the Oracle RAC event mechanism. This means that Fast Connection Failover is efficient and detects failures quickly for both active and inactive connections.

- Load-balancing support

  Fast Connection Failover supports `UP` event load balancing of connections and run-time work request distribution across active Oracle RAC instances.

> **See Also**
>
> *Oracle Universal Connection Pool for JDBC Developer's Guide*

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> **Note**
>
> Oracle recommends *not* to use TAF and Fast Connection Failover in the same application.

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36
Single Client Access Name

Single Client Access Name (SCAN) is an Oracle Real Application Clusters (Oracle RAC) feature that provides a single name for clients to access Oracle Databases running in a cluster. This chapter discusses the following concepts related to the SCAN:

- Overview of Single Client Access Name
- About Configuring the Database Using the SCAN
- Using the SCAN in a Maximum Availability Architecture Environment
- Using the SCAN With Oracle Connection Manager

36.1 Overview of Single Client Access Name

> **Note**
>
> The Highly Available Grid Naming Service feature of Grid Naming Service (GNS) in Oracle Grid Infrastructure is deprecated in Oracle Database 23ai.

The SCAN is a domain name registered to at least one and up to three IP addresses, either in Domain Naming Service (DNS) or Grid Naming Service (GNS). When you use GNS and Dynamic Host Configuration Protocol (DHCP), Oracle Clusterware configures the Virtual IP (VIP) addresses for the SCAN name that is provided during cluster configuration. The node VIP and the three SCAN VIPs are obtained from the DHCP server when you use GNS.

> **See Also**
>
> *Oracle Clusterware Administration and Deployment Guide* for more information about GNS

If a new server joins the cluster, then Oracle Clusterware dynamically obtains the required VIP address from the DHCP server, updates the cluster resource, and makes the server accessible through GNS. The benefit of using the SCAN is that the connection information of the client does not need to change if you add or remove nodes in the cluster. Having a single name to access the cluster enables the client to use the Easy Connect client and the simple JDBC thin URL to access any Database running in the cluster, independent of the active servers in the cluster. The SCAN provides load balancing and failover for client connections to the Database. The SCAN works as a cluster alias for Databases in the cluster.

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36.2 About Configuring the Database Using the SCAN

The SCAN is an essential part of Database configuration. So, by default, the `REMOTE_LISTENER` parameter is set to the SCAN, assuming that the Database is created using standard Oracle tools.

This enables the instances to register with the SCAN Listeners as remote listeners to provide information on what services are being provided by the instance, the current load, and a recommendation on how many incoming connections should be directed to the instance.

In this context, you must set the `LOCAL_LISTENER` parameter to the node-VIP. If you need fully qualified domain names, then ensure that the `LOCAL_LISTENER` parameter is set to the fully qualified domain name. By default, a node listener is created on each node in the cluster during cluster configuration. With Oracle Grid Infrastructure, the node listener runs out of the Oracle Grid Infrastructure home and listens on the node-VIP using the specified port. The default port is 1521.

Unlike in earlier Database versions, Oracle does not recommend to set your `REMOTE_LISTENER` parameter to a server side `TNSNAMES` alias that resolves the host to the SCAN in the address list entry, for example, `HOST=sales1-scan`. Instead, you must use the simplified `SCAN:port` syntax as shown in the following table that shows typical setting for a `LOCAL_LISTENER` and `REMOTE_LISTENER`:

Name	Type	Value
`LOCAL_LISTENER`	string	`(DESCRIPTION=(ADDRESS_LIST=(ADDRESS=(PROTOCOL=TCP)(HOST=localhost)(PORT=5221))))`
`REMOTE_LISTENER`	string	`myoracleexample.com:5221`

> **Note**
>
> If you are using the easy connect naming method, you may need to modify the `SQLNET.ORA` file to ensure that `EZCONNECT` is in the list when you specify the order of the naming methods used for the client name resolution lookups.

36.3 How Connection Load Balancing Works Using the SCAN

For clients connecting using Oracle SQL*Net, three IP addresses are received by the client by resolving the SCAN name through DNS. The client then goes through the list that it receives from the DNS and tries connecting through one of the IP addresses in the list. If the client receives an error, then it tries connecting to the other addresses before returning an error to the user or application. This is similar to how client connection failover works in earlier Database releases, when an address list is provided in the client connection string.

When a SCAN Listener receives a connection request, the SCAN Listener checks for the least loaded instance providing the requested service. It then re-directs the connection request to the local listener on the node where the least loaded instance is running. Subsequently, the client is given the address of the local listener. The local listener then finally creates the connection to the Database instance.

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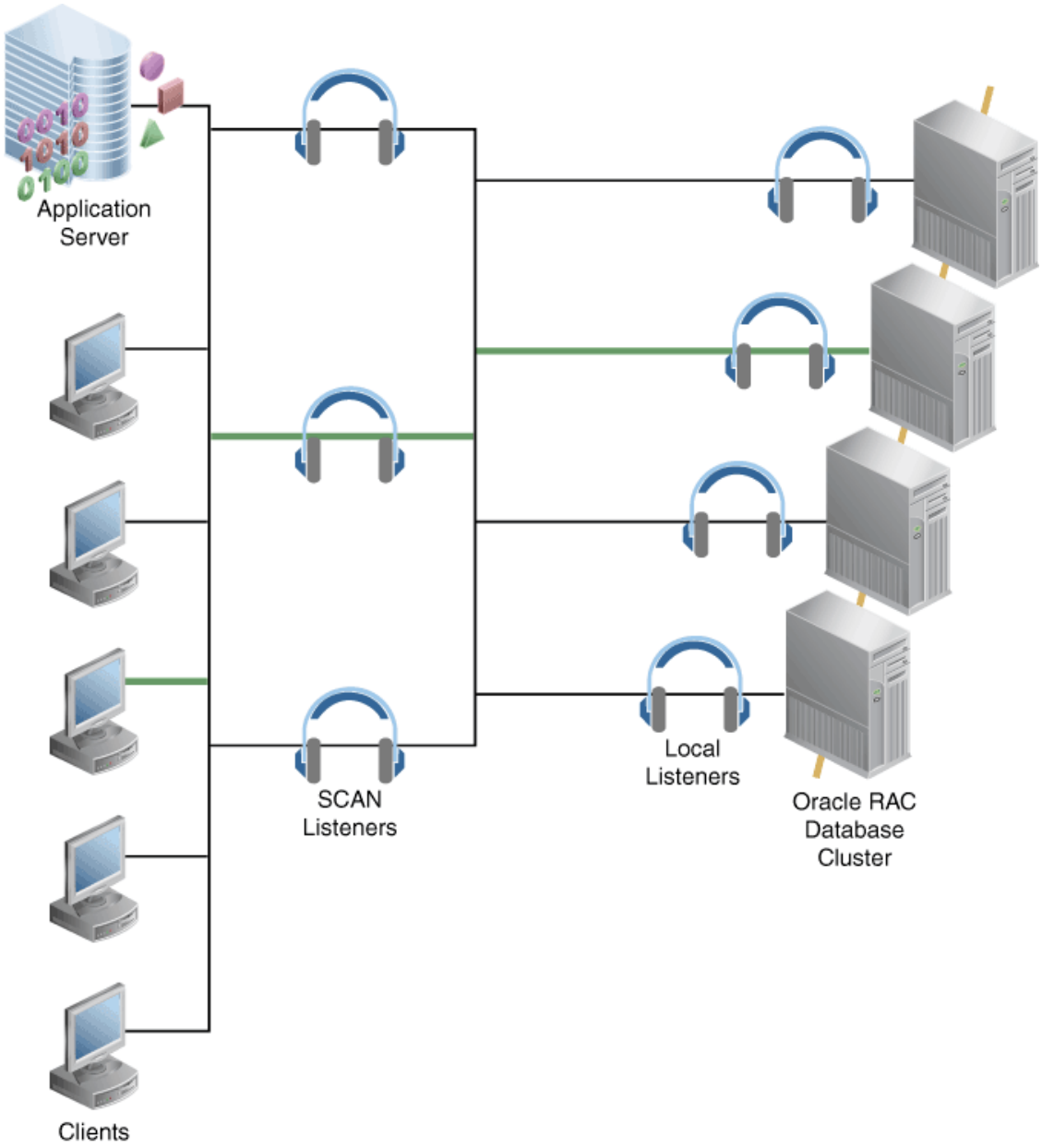
Figure 36-1 Connection Load Balancing Using the SCAN



Example

This example assumes an Oracle client using a default `TNSNAMES.ora` file:

```
ORCLservice =(DESCRIPTION =(ADDRESS = (PROTOCOL = TCP)(HOST = sales1-scan.example.com)
(PORT = 1521))(CONNECT_DATA =(SERVER = DEDICATED)(SERVICE_NAME = MyORCLservice)))
```

36.4 Version and Backward Compatibility

This section describes how to use the SCAN for connecting to an Oracle RAC Database.

To successfully use the SCAN to connect to an Oracle RAC Database in the cluster depends on the following two factors:

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- Ability of the client to understand and use the SCAN
- The correct configuration of the `REMOTE_LISTENER` parameter setting in the Database

If the version of the Oracle Client connecting to the Database and the Oracle Database version used are both Oracle Database 11*g* Release 2, and the default configuration is used as described in the preceding sections, then typically you do not need to make any change to the system.

If both the Oracle Client version and the version of the Oracle Database that the client is connecting to are earlier than Oracle Database 11*g* Release 2, then typically you do not need to make any change to the system. In this case, the client uses a TNS connect descriptor that resolves to the node-VIPs of the cluster, while Oracle Database uses a `REMOTE_LISTENER` entry pointing to the node-VIPs. The disadvantage of this configuration is that the SCAN is not used and therefore every time the cluster changes in the back end, the clients are exposed to changes.

If you are using Oracle Database 11*g* Release 2, but the clients are on an earlier version of the Database, then you must change the Oracle client, or the Oracle Database `REMOTE_LISTENER` parameter settings, or both accordingly. You must consider the following cases in such a scenario:

Table 36-1 Oracle Client and Oracle Database Version Compatibility for the SCAN

Oracle Client Version	Oracle Database Version	Comment
Oracle Database 11*g* Release 2	Oracle Database 11*g* Release 2	No change is required
Oracle Database 11*g* Release 2	Oracle Database Version earlier than Oracle Database 11*g* Release 2	Add the SCAN VIPs as hosts to the `REMOTE_LISTENER` parameter.
Oracle Database Version earlier than Oracle Database 11*g* Release 2	Oracle Database 11*g* Release 2	Update the client `TNSNAMES.ora` file to include the SCAN VIPs. If the Database is upgraded using the Database AutoUpgrade from a Database earlier than 11*g* Release 2, then the Database AutoUpgrade configures the `REMOTE_LISTENER` parameter to point to the node-VIPs and the SCAN.
Oracle Database Version earlier than Oracle Database 11*g* Release 2	Oracle Database Version earlier than Oracle Database 11*g* Release 2	If you want to make use of the SCAN (recommended), then add the SCAN VIPs as hosts to the `REMOTE_LISTENER` parameter and update the client `TNSNAMES.ora` file to include the SCAN VIPs. Otherwise, no change required.

If you are using a client earlier than Oracle Database 11*g* Release 2, then you cannot fully benefit from the advantages of the SCAN because the Oracle Client cannot handle a set of three IP addresses returned by the DNS for the SCAN. Instead, it tries to connect to only the first address returned in the list and ignores the other two addresses. If the SCAN Listener listening on this specific IP address is not available or the IP address itself is not available, then the connection fails. To ensure load balancing and connection failover with clients earlier than Oracle Database 11*g* Release 2, you must update the `TNSNAMES.ora` file of the client, so that it uses three address lines, where each address line resolves to one of the SCAN VIPs.

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The following example shows a sample TNSNAMES.ora file for a client earlier than Oracle Database 11*g* Release 2:

```
sales.example.com =(DESCRIPTION=
(ADDRESS_LIST= (LOAD_BALANCE=on)(FAILOVER=ON)
(ADDRESS=(PROTOCOL=tcp)(HOST=133.22.67.192)(PORT=1521))
(ADDRESS=(PROTOCOL=tcp)(HOST=133.22.67.193)(PORT=1521))
(ADDRESS=(PROTOCOL=tcp)(HOST=133.22.67.194)(PORT=1521)))
(CONNECT_DATA=(SERVICE_NAME= salesservice.example.com)))
```

36.5 Using the SCAN in a Maximum Availability Architecture Environment

If you have a Maximum Availability Architecture (MAA) environment implemented, in which you use Oracle RAC for both your primary and standby Databases that are synchronized using Oracle Data Guard, then using the SCAN provides a simplified TNSNAMES configuration that a client can use to connect to the Database, independent of whether the primary or standby Database is the currently active Database.

To use this simplified configuration, Oracle Database 11*g* Release 2 introduced the following two SQL*Net parameters that can be used for connection strings of individual clients:

- The CONNECT_TIMEOUT parameter

  It specifies the timeout duration in seconds for a client to establish an Oracle Net connection to an Oracle Database. This parameter overrides the SQLNET.OUTBOUT_CONNECT_TIMEOUT parameter in the SQLNET.ORA file.

- The RETRY_COUNT parameter

  It specifies the number of times an ADDRESS_LIST is traversed before the connection attempt is terminated.

Using these two parameters, both the SCANs, the one on the primary site and the one on the standby site, can be used in the client connection strings. Also, if the randomly selected address points to the site that is not currently active, then the timeout enables the connection request to failover before the client waits for an unreasonably long time. The following example shows a sample TNSNAMES.ORA entry for a MAA environment:

```
sales.example.com =(DESCRIPTION= (CONNECT_TIMEOUT=10)(RETRY_COUNT=3)
(ADDRESS_LIST= (LOAD_BALANCE=on)(FAILOVER=ON)
(ADDRESS=(PROTOCOL=tcp)(HOST=sales1-scan)(PORT=1521))
(ADDRESS=(PROTOCOL=tcp)(HOST=sales2-scan)(PORT=1521)))
(CONNECT_DATA=(SERVICE_NAME= salesservice.example.com)))
```

36.6 Using the SCAN With Oracle Connection Manager

If you use Oracle Connection Manager (CMAN) with your Oracle RAC Database, then the REMOTE_LISTENER parameter for the Oracle RAC instances must include the CMAN server, so that the CMAN server receives load balancing related information and can load balance connections across the available instances. The easiest way to achieve this is to add the CMAN server as an entry to the REMOTE_LISTENER parameter of the Databases that clients want to connect to through CMAN. You must also remove the SCAN from the TNSNAMES connect descriptor of the clients and configure the CMAN server. The following example shows a server-side TNSNAMES.ora example entry when you use CMAN:

```
SQL> show parameters listener
NAME                 TYPE         VALUE
```


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```
------------------------- ----------- ------------------------------
listener_networks   string
local_listener      string      (DESCRIPTION=(ADDRESS_LIST=
                                (ADDRESS=(PROTOCOL=TCP)
                                (HOST=148.87.58.109)(PORT=1521))))
remote_listener     string      stscan3.oracle.com:1521,(DESCRIPTION=
                                (ADDRESS_LIST=(ADDRESS=(PROTOCOL=TCP)
                                (HOST=CMANserver)(PORT=1521))))
```

See Also

Oracle Database Net Services Reference for more information about configuring the CMAN server

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Part VII
Transaction Management

This part provides information about transaction management in Oracle Java Database Connectivity (JDBC). It includes a chapter that discusses the Oracle JDBC implementation of distributed transactions.

Part VII contains the following chapter:

- Distributed Transactions

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37
Distributed Transactions

This chapter discusses the Oracle Java Database Connectivity (JDBC) implementation of distributed transactions. These are multiphased transactions, often using multiple databases, which must be committed in a coordinated way. There is also related discussion of XA, which is a general standard, and not specific to Java, for distributed transactions.

The following topics are discussed:

- AboutDistributed Transactions
- XA Components
- Error Handling and Optimizations
- About Implementing a Distributed Transaction
- Native-XA in Oracle JDBC Drivers

> **Note**
>
> This chapter discusses features of the JDBC 2.0 Optional Package, formerly known as the JDBC 2.0 Standard Extension application programming interface (API) that is available through the `javax` packages.

For further introductory and general information about distributed transactions, refer to the specifications for the JDBC 2.0 Optional Package and the Java Transaction API (JTA).

37.1 About Distributed Transactions

The section covers the following topics:

- Overview of Distributed Transaction
- Distributed Transaction Components and Scenarios
- Distributed Transaction Concepts
- About Switching Between Global and Local Transactions
- Oracle XA Packages

37.1.1 Overview of Distributed Transaction

A **distributed transaction**, sometimes referred to as a **global transaction**, is a set of two or more related transactions that must be managed in a coordinated way. The transactions that constitute a distributed transaction might be in the same database, but more typically are in different databases and often in different locations. Each individual transaction of a distributed transaction is referred to as a **transaction branch**.

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For example, a distributed transaction might consist of money being transferred from an account in one bank to an account in another bank. You would not want either transaction committed without assurance that both will complete successfully.

In JDBC, distributed transaction functionality is built on top of connection pooling functionality. This distributed transaction functionality is also built upon the open XA standard for distributed transactions. XA is part of the X/Open standard and is not specific to Java.

JDBC is used to connect to database resources. However, to include all changes to multiple databases within a transaction, you must use the JDBC connections within a JTA global transaction. The process of including database SQL updates within a transaction is referred to as enlisting a database resource.

37.1.2 Distributed Transaction Components and Scenarios

In reading the remainder of the distributed transactions section, it will be helpful to keep the following points in mind:

- A distributed transaction system typically relies on an external transaction manager, such as a software component that implements standard JTA functionality, to coordinate the individual transactions.

  Many vendors offer XA-compliant JTA modules, including Oracle, which includes JTA in Oracle9*i* Application Server and Oracle Application Server 10*g*.
- XA functionality is usually isolated from a client application, being implemented instead in a middle-tier environment, such as an application server.

  In many scenarios, the application server and transaction manager will be together on the middle tier, possibly together with some of the application code as well.
- Discussion throughout this section is intended mostly for middle-tier developers.
- The term resource manager is often used in discussing distributed transactions. A resource manager is simply an entity that manages data or some other kind of resource. Wherever the term is used in this chapter, it refers to a database.

> **Note**
>
> Using JTA functionality requires `jta.jar` to be in the `CLASSPATH` environment variable. This file is located at *`ORACLE_HOME`*`/jlib`. Oracle includes this file with the JDBC product.

37.1.3 Distributed Transaction Concepts

When you use XA functionality, the transaction manager uses XA resource instances to prepare and coordinate each transaction branch and then to commit or roll back all transaction branches appropriately.

XA functionality includes the following key components:

- XA data sources

  These are extensions of connection pool data sources and other data sources, and similar in concept and functionality.

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There will be one XA data source instance for each resource manager that will be used in the distributed transaction. You will typically create XA data source instances in your middle-tier software.

XA data sources produce XA connections.

- XA connections

  These are extensions of pooled connections and similar in concept and functionality. An XA connection encapsulates a physical database connection. Individual connection instances are temporary handles to these physical connections.

  An XA connection instance corresponds to a single Oracle session, although the session can be used in sequence by multiple logical connection instances, as with pooled connection instances.

  You will typically get an XA connection instance from an XA data source instance in your middle-tier software. You can get multiple XA connection instances from a single XA data source instance if the distributed transaction will involve multiple sessions in the same database.

  XA connections produce `OracleXAResource` instances and JDBC connection instances.

- XA resources

  These are used by a transaction manager in coordinating the transaction branches of a distributed transaction.

  You will get one `OracleXAResource` instance from each XA connection instance, typically in your middle-tier software. There is a one-to-one correlation between `OracleXAResource` instances and XA connection instances. Equivalently, there is a one-to-one correlation between `OracleXAResource` instances and Oracle sessions.

  In a typical scenario, the middle-tier component will hand off `OracleXAResource` instances to the transaction manager, for use in coordinating distributed transactions.

  Each `OracleXAResource` instance corresponds to a single Oracle session. So, there can be only a single active transaction branch associated with an `OracleXAResource` instance at any given time. However, there can be additional suspended transaction branches.

  Each `OracleXAResource` instance has the functionality to start, end, prepare, commit, or roll back the operations of the transaction branch running in the session with which the `OracleXAResource` instance is associated.

  The prepare step is the first step of a two-phase commit operation. The transaction manager will issue a `PREPARE` to each `OracleXAResource` instance. Once the transaction manager sees that the operations of each transaction branch have prepared successfully, it will issue a `COMMIT` to each `OracleXAResource` instance to commit all the changes.

- Transaction IDs

  These are used to identify transaction branches. Each ID includes a transaction branch ID component and a distributed transaction ID component. This is how a branch is associated with a distributed transaction. All `OracleXAResource` instances associated with a given distributed transaction would have a transaction ID that includes the same distributed transaction ID component.

- `OracleXAResource.ORATRANSLOOSE`

  Start a loosely coupled transaction with transaction ID `xid`.

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37.1.4 About Switching Between Global and Local Transactions

Applications can share connections between local and global transactions. Applications can also switch connections between local transactions and global transactions.

A connection is always in one of the following modes:

- `NO_TXN`

  No transaction is actively using this connection.

- `LOCAL_TXN`

  A local transaction with auto-commit turned off or disabled is actively using this connection.

- `GLOBAL_TXN`

  A global transaction is actively using this connection.

Each connection switches automatically between these modes depending on the operations carried out on the connection. A connection is always in `NO_TXN` mode when it is instantiated.

> **Note**
>
> The modes are maintained internally by the JDBC drivers in association with Oracle Database.

Table 37-1 describes the connection mode transition rules.

Table 37-1 Connection Mode Transitions

Current Mode	Switches to NO_TXN When	Switches to LOCAL_TXN When	Switches to GLOBAL_TXN When
`NO_TXN`	NA	Auto-commit mode is false and an Oracle data manipulation language (DML) statement is run.	The `start` method is called on an `XAResource` obtained from the `XAconnection` that provided the current connection.
`LOCAL_TXN`	Any of the following happens: • An Oracle data definition language (DDL) statement is run. • `commit` is called. • `rollback` is called, but without parameters.	NA	The `start` method is called on an `XAResource` obtained from the `XAconnection` that provided the current connection. This feature is available starting from Oracle Database 12*c* Release 1 (12.1.0.2).
`GLOBAL_TXN`	Within a global transaction open on this connection, `end` is called on an `XAResource` obtained from the `XAconnection` that provided this connection.	NEVER	NA

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If none of these rules is applicable, then the mode does not change.

Mode Restrictions on Operations

The current connection mode restricts which operations are valid within a transaction.

- In the `LOCAL_TXN` mode, applications must not call `prepare`, `commit`, `rollback`, `forget`, or `end` on an `XAResource`. Doing so causes an `XAException` to be thrown.
- In the `GLOBAL_TXN` mode, applications must not call `commit`, `rollback`, `rollback(Savepoint)`, `setAutoCommit(true)`, or `setSavepoint` on a `java.sql.Connection`, and must not call `OracleSetSavepoint` or `oracleRollback` on an `oracle.jdbc.OracleConnection`. Doing so causes a `SQLException` to be thrown.

> **Note**
>
> This mode-restriction error checking is in addition to the standard error checking on the transaction and savepoint APIs.

37.1.5 Oracle XA Packages

Oracle supplies the following three packages that have classes to implement distributed transaction functionality according to the XA standard:

- `oracle.jdbc.xa`
- `oracle.jdbc.xa.client`
- `oracle.jdbc.xa.server`

Classes for XA data sources, XA connections, and XA resources are in both the `client` package and the `server` package. An abstract class for each is in the top-level package. The `OracleXid` and `OracleXAException` classes are in the top-level `oracle.jdbc.xa` package, because their functionality does not depend on where the code is running.

In middle-tier scenarios, you will import `OracleXid`, `OracleXAException`, and the `oracle.jdbc.xa.client` package.

If you intend your XA code to run in the target Oracle Database, however, you will import the `oracle.jdbc.xa.server` package instead of the `client` package.

If code that will run inside a target database must also access remote databases, then do not import either package. Instead, you must fully qualify the names of any classes that you use from the `client` package to access a remote database or from the `server` package to access the local database. Class names are duplicated between these packages.

37.2 XA Components

This section discusses the XA components, that is, the standard XA interfaces specified in the JDBC standard, and the Oracle classes that implement them. The following topics are covered:

- XADatasource Interface and Oracle Implementation
- XAConnection Interface and Oracle Implementation
- XAResource Interface and Oracle Implementation
- OracleXAResource Method Functionality and Input Parameters

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- Xid Interface and Oracle Implementation

37.2.1 XADatasource Interface and Oracle Implementation

The `javax.sql.XADataSource` interface outlines standard functionality of XA data sources, which are factories for XA connections. The overloaded `getXAConnection` method returns an XA connection instance and optionally takes a user name and password as input:

```
public interface XADataSource
{
   XAConnection getXAConnection() throws SQLException;
   XAConnection getXAConnection(String user, String password)
      throws SQLException;
   ...
}
```

Oracle JDBC implements the `XADataSource` interface with the `OracleXADataSource` class, located both in the `oracle.jdbc.xa.client package` and the `oracle.jdbc.xa.server` package.

The `OracleXADataSource` classes also extend the `OracleConnectionPoolDataSource` class, which extends the `OracleDataSource` class, and therefore, include all the connection properties.

The `getXAConnection` methods of the `OracleXADataSource` class returns the Oracle implementation of XA connection instances, which are `OracleXAConnection` instances.

> **Note**
>
> You can register XA data sources in Java Naming Directory and Interface (JNDI) using the same naming conventions as discussed previously for nonpooling data sources.

> **See Also**
>
> For information about Fast Connection Failover, refer to *Oracle Universal Connection Pool for JDBC Developer's Guide*.

37.2.2 XAConnection Interface and Oracle Implementation

An XA connection instance, as with a pooled connection instance, encapsulates a physical connection to a database. This would be the database specified in the connection properties of the XA data source instance that produced the XA connection instance.

Each XA connection instance also has the facility to produce the `OracleXAResource` instance that will correspond to it for use in coordinating the distributed transaction.

An XA connection instance is an instance of a class that implements the standard `javax.sql.XAConnection` interface:

```
public interface XAConnection extends PooledConnection
{
   javax.jta.xa.XAResource getXAResource() throws SQLException;
}
```


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As you see, the `XAConnection` interface extends the `javax.sql.PooledConnection` interface, so it also includes the `getConnection`, `close`, `addConnectionEventListener`, and `removeConnectionEventListener` methods.

Oracle JDBC implements the `XAConnection` interface with the `OracleXAConnection` class, located both in the `oracle.jdbc.xa.client package` and the `oracle.jdbc.xa.server` package.

The `OracleXAConnection` classes also extend the `OraclePooledConnection` class.

The `OracleXAConnection` class `getXAResource` method returns the Oracle implementation of an `OracleXAResource` instance, which is an `OracleXAResource` instance. The `getConnection` method returns an `OracleConnection` instance.

A JDBC connection instance returned by an XA connection instance acts as a temporary handle to the physical connection, as opposed to encapsulating the physical connection. The physical connection is encapsulated by the XA connection instance. The connection obtained from an `XAConnection` object behaves exactly like a regular connection, until it participates in a global transaction. At that time, auto-commit status is set to `false`. After the global transaction ends, auto-commit status is returned to the value it had before the global transaction. The default auto-commit status on a connection obtained from `XAConnection` is `false` in all releases prior to Oracle Database 10*g*. Starting from Oracle Database 10*g*, the default status is `true`.

Each time an XA connection instance `getConnection` method is called, it returns a new connection instance that exhibits the default behavior, and closes any previous connection instance that still exists and had been returned by the same XA connection instance. However, it is advisable to explicitly close any previous connection instance before opening a new one.

Calling the `close` method of an XA connection instance closes the physical connection to the database. This is typically performed in the middle tier.

37.2.3 XAResource Interface and Oracle Implementation

The transaction manager uses `OracleXAResource` instances to coordinate all the transaction branches that constitute a distributed transaction.

Each `OracleXAResource` instance provides the following key functionality, typically invoked by the transaction manager:

- It associates and disassociates distributed transactions with the transaction branch operating in the XA connection instance that produced this `OracleXAResource` instance. Essentially, it associates distributed transactions with the physical connection or session encapsulated by the XA connection instance. This is done through use of transaction IDs.
- It performs the two-phase commit functionality of a distributed transaction to ensure that changes are not committed in one transaction branch before there is assurance that the changes will succeed in all transaction branches.

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> **Note**
>
> – Because there must always be a one-to-one correlation between XA connection instances and `OracleXAResource` instances, an `OracleXAResource` instance is implicitly closed when the associated XA connection instance is closed.
>
> – If a transaction is opened by a given `OracleXAResource` instance, then it must also be closed by the same `OracleXAResource` instance.

An `OracleXAResource` instance is an instance of a class that implements the standard `javax.transaction.xa.XAResource` interface. Oracle JDBC implements the `XAResource` interface with the `OracleXAResource` class, located both in the `oracle.jdbc.xa.client` package and the `oracle.jdbc.xa.server` package.

Oracle JDBC driver creates and returns an `OracleXAResource` instance whenever the `getXAResource` method of the `OracleXAConnection` class is called, and it is Oracle JDBC driver that associates an `OracleXAResource` instance with a connection instance and the transaction branch being run through that connection.

This method is how an `OracleXAResource` instance is associated with a particular connection and with the transaction branch being run in that connection.

37.2.4 OracleXAResource Method Functionality and Input Parameters

The `OracleXAResource` class has several methods to coordinate a transaction branch with the distributed transaction with which it is associated. This functionality usually involves two-phase commit operations.

A transaction manager, receiving `OracleXAResource` instances from a middle-tier component, such as an application server, typically invokes this functionality.

Each of these methods takes a transaction ID as input, in the form of an `Xid` instance, which includes a transaction branch ID component and a distributed transaction ID component. Every transaction branch has a unique transaction ID, but transaction branches belonging to the same global transaction have the same global transaction component as part of their transaction IDs.

start

Starts work on behalf of a transaction branch, associating the transaction branch with a distributed transaction.

```
void start(Xid xid, int flags)
```

The `flags` parameter must be one or more of the following values:

- `XAResource.TMNOFLAGS`

  Flags the start of a new transaction branch for subsequent operations in the session associated with this XA resource instance. This branch will have the transaction ID `xid`, which is an `OracleXid` instance created by the transaction manager. This will map the transaction branch to the appropriate distributed transaction.

- `XAResource.TMJOIN`

  Joins subsequent operations in the session associated with this XA resource instance to the existing transaction branch specified by `xid`.

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- `XAResource.TMRESUME`

  Resumes the transaction branch specified by `xid`.

  > **Note**
  >
  > A transaction branch can be resumed only if it had been suspended earlier.

- `OracleXAResource.TMPROMOTE`

  Promotes a local transaction to a global transaction

- `OracleXAResource.ORATMSERIALIZABLE`

  Starts a serializable transaction with transaction ID `xid`.

- `OracleXAResource.ORATMREADONLY`

  Starts a read-only transaction with transaction ID `xid`.

- `OracleXAResource.ORATMREADWRITE`

  Starts a read/write transaction with transaction ID `xid`.

- `OracleXAResource.ORATRANSLOOSE`

  Starts a loosely coupled transaction with transaction ID `xid`.

`TMNOFLAGS`, `TMJOIN`, `TMRESUME`, `TMPROMOTE`, `ORATMSERIALIZABLE`, `ORATMREADONLY`, and `ORATMREADWRITE` are defined as `static` members of the `XAResource` interface and `OracleXAResource` class. `ORATMSERIALIZABLE`, `ORATMREADONLY`, and `ORATMREADWRITE` are the isolation-mode flags. The default isolation behavior is `READ COMMITTED`.

> **Note**
>
> - Instead of using the `start` method with `TMRESUME`, the transaction manager can cast to `OracleXAResource` and use the `resume(Xid xid)` method, an Oracle extension.
> - If you use `TMRESUME`, then you must also use `TMNOMIGRATE`, as in `start(xid, XAResource.TMRESUME | OracleXAResource.TMNOMIGRATE)`. This prevents the application from receiving the error `ORA 1002: fetch out of sequence`.
> - If you use the isolation-mode flags incorrectly, then an exception with code `XAER_INVAL` is raised. Furthermore, you cannot use isolation-mode flags when resuming a global transaction, because you cannot set the isolation level of an existing transaction. If you try to use the isolation-mode flags when resuming a transaction, then an external Oracle exception with code ORA-24790 is raised.
> - In order to avoid `Error ORA 1002: fetch out of sequence`, include the `TMNOMIGRATE` flag as part of the `start` method. For example:
>
>   ```
>   start(xid, XAResource.TMSUSPEND | OracleXAResource.TMNOMIGRATE);
>   ```
>
> - All the flags defined in `OracleXAResource` are Oracle extensions. When writing a transaction manager that uses these flags, you should be mindful of this.

Note that to create an appropriate transaction ID in starting a transaction branch, the transaction manager must know to which distributed transaction the transaction branch belongs. The mechanics of this are handled between the middle tier and transaction manager.

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end

Ends work on behalf of the transaction branch specified by `xid`, disassociating the transaction branch from its distributed transaction.

```
void end(Xid xid, int flags)
```

The `flags` parameter can have one of the following values:

- `XAResource.TMSUCCESS`

  This is to indicate that this transaction branch is known to have succeeded.

- `XAResource.TMFAIL`

  This is to indicate that this transaction branch is known to have failed.

- `XAResource.TMSUSPEND`

  This is to suspend the transaction branch specified by `xid`. By suspending transaction branches, you can have multiple transaction branches in a single session. Only one can be active at any given time, however. Also, this tends to be more expensive in terms of resources than having two sessions.

`TMSUCCESS`, `TMFAIL`, and `TMSUSPEND` are defined as static members of the `XAResource` interface and `OracleXAResource` class.

> **Note**
>
> - Instead of using the `end` method with `TMSUSPEND`, the transaction manager can cast to `OracleXAResource` and use the `suspend(Xid xid)` method, an Oracle extension.
> - This XA functionality to suspend a transaction provides a way to switch between various transactions within a single JDBC connection. You can use the XA classes to accomplish this, even if you are not in a distributed transaction environment and would otherwise have no need for the XA classes.
> - If you use `TMSUSPEND`, then you must also use `TMNOMIGRATE`, as in `end(xid, XAResource.TMSUSPEND | OracleXAResource.TMNOMIGRATE)`. This prevents the application from receiving the error `ORA 1002: fetch out of sequence`.
> - In order to avoid `Error ORA 1002: fetch out of sequence`, include the `TMNOMIGRATE` flag as part of the end method. For example:
>
>   ```
>   end(xid, XAResource.TMSUSPEND | OracleXAResource.TMNOMIGRATE);
>   ```
>
> - All the flags defined in `OracleXAResource` are Oracle extensions. Any transaction manager that uses these flags should take heed of this.

prepare

Prepares the changes performed in the transaction branch specified by `xid`. This is the first phase of a two-phase commit operation, to ensure that the database is accessible and that the changes can be committed successfully.

```
int prepare(Xid xid)
```

This method returns an integer value as follows:

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- `XAResource.XA_RDONLY`

  This is returned if the transaction branch runs only read-only operations such as `SELECT` statements.

- `XAResource.XA_OK`

  This is returned if the transaction branch runs updates that are all prepared without error.

`XA_RDONLY` and `XA_OK` are defined as `static` members of the `XAResource` interface and `OracleXAResource` class.

> **Note**
>
> - The `prepare` method sometimes does not return any value if the transaction branch runs updates and any of them encounters errors during preparation. In this case, an XA exception is thrown.
> - Always call the `end` method on a branch before calling the `prepare` method.
> - If there is only one transaction branch in a distributed transaction, then there is no need to call the `prepare` method. You can call the `OracleXAResource commit` method without preparing first.

commit

Commits prepared changes in the transaction branch specified by `xid`. This is the second phase of a two-phase commit and is performed only after all transaction branches have been successfully prepared.

```
void commit(Xid xid, boolean onePhase)
```

Set the `onePhase` parameter as follows:

- `true`

  This is to use one-phase instead of two-phase protocol in committing the transaction branch. This is appropriate if there is only one transaction branch in the distributed transaction; the `prepare` step would be skipped.

- `false`

  This is to use two-phase protocol in committing the transaction branch.

rollback

Rolls back prepared changes in the transaction branch specified by `xid`.

```
void rollback(Xid xid)
```

forget

Tells the resource manager to forget about a heuristically completed transaction branch.

```
public void forget(Xid xid)
```

recover

The transaction manager calls this method during recovery to obtain the list of transaction branches that are currently in prepared or heuristically completed states.

```
public Xid[] recover(int flag)
```


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> **Note**
>
> Values for `flag` other than `TMSTARTRSCAN`, `TMENDRSCAN`, or `TMNOFLAGS`, cause an exception to be thrown, otherwise `flag` is ignored.

The resource manager returns zero or more `Xids` for the transaction branches that are currently in a prepared or heuristically completed state. If an error occurs during the operation, then the resource manager throws the appropriate `XAException`.

> **Note**
>
> The `recover` method requires SELECT privilege on `DBA_PENDING_TRANSACTIONS` and EXECUTE privilege on `SYS.DBMS_XA` in Oracle database server. For database versions prior to Oracle Database 11*g* Release 1, where an Oracle patch including a fix for bug 5945463 is not available, or it is infeasible to apply the patch for the particular application scenario, the `recover` method requires `SYSBDBA` privilege. Regular use of `SYSDBA` privilege is a security risk. So, Oracle strongly recommends that you upgrade your Database or apply the fix for bug 5945463, if you need to use the `recover` method.

isSameRM

To determine if two `OracleXAResource` instances correspond to the same resource manager, call the `isSameRM` method from one `OracleXAResource` instance, specifying the other `OracleXAResource` instance as input. In the following example, presume `xares1` and `xares2` are `OracleXAResource` instances:

```
boolean sameRM = xares1.isSameRM(xares2);
```

37.2.5 Xid Interface and Oracle Implementation

The transaction manager creates transaction ID instances and uses them in coordinating the branches of a distributed transaction. Each transaction branch is assigned a unique transaction ID, which includes the following information:

- Format identifier

  A format identifier specifies a Java transaction manager. For example, there could be a format identifier `orcl`. This field *cannot* be null. The size of a format identifier is 4 bytes.

- Global transaction identifier

  It is also known as a distributed transaction ID component. The size of a global transaction identifier is 64 bytes.

- Branch qualifier

  It is also known as transaction branch ID component. The size of a branch qualifier is 64 bytes.

The 64-byte global transaction identifier value will be identical in the transaction IDs of all transaction branches belonging to the same distributed transaction. However, the overall transaction ID is unique for every transaction branch.

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An XA transaction ID instance is an instance of a class that implements the standard `javax.transaction.xa.Xid` interface, which is a Java mapping of the X/Open transaction identifier XID structure.

Oracle implements this interface with the `OracleXid` class in the `oracle.jdbc.xa` package. `OracleXid` instances are employed only in a transaction manager, transparent to application programs or an application server.

> **Note**
>
> Oracle does not require the use of `OracleXid` for `OracleXAResource` calls. Instead, use any class that implements the `javax.transaction.xa.Xid` interface.

A transaction manager may use the following in creating an `OracleXid` instance:

```
public OracleXid(int fId, byte gId[], byte bId[]) throws XAException
```

`fId` is an integer value for the format identifier, `gId[]` is a byte array for the global transaction identifier, and `bId[]` is a byte array for the branch qualifier.

The `Xid` interface specifies the following getter methods:

- `public int getFormatId()`
- `public byte[] getGlobalTransactionId()`
- `public type[] getBranchQualifier()`

37.3 Error Handling and Optimizations

This section focuses on the functionality of XA exceptions and error handling and the Oracle optimizations in its XA implementation. It covers the following topics:

- XAException Classes and Methods
- Mapping Between Oracle Errors and XA Errors
- XA Error Handling
- Oracle XA Optimizations

The exception and error-handling discussion includes the standard XA exception class and the Oracle-specific XA exception class, as well as particular XA error codes and error-handling techniques.

37.3.1 XAException Classes and Methods

XA methods throw XA exceptions, as opposed to general exceptions or `SQLExceptions`. An XA exception is an instance of the standard class `javax.transaction.xa.XAException` or a subclass.

An Oracle XAException is an instance that consists of an Oracle error portion and an XA error portion. Oracle provides the `oracle.jdbc.xa.OracleXAException` subclasses of the standard `javax.transaction.xa.XAException` class. An `OracleXAException` instance is constructed using one of the following constructors:

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```
public OracleXAException()

public OracleXAException(int error)
```

The error value is an error code that combines an Oracle SQL error value and an XA error value. The JDBC driver determines exactly how to combine the Oracle and XA error values.

The `OracleXAException` class has the following methods:

- `public int getOracleError()`

  This method returns the Oracle SQL error code pertaining to the exception, a standard ORA error number or 0 if there is no Oracle SQL error.

- `public int getXAError()`

  This method returns the XA error code pertaining to the exception. XA error values are defined in the `javax.transaction.xa.XAException` class.

37.3.2 Mapping Between Oracle Errors and XA Errors

Oracle errors correspond to XA errors in `OracleXAException` instances as documented in Table 37-2.

Table 37-2 Oracle-XA Error Mapping

Oracle Error Code	XA Error Code
ORA 24756	XAException.XAER_NOTA
ORA 24764	XAException.XA_HEURCOM
ORA 24765	XAException.XA_HEURRB
ORA 24766	XAException.XA_HEURMIX
ORA 24767	XAException.XA_RDONLY
ORA 25351	XAException.XA_RETRY
ORA 30006	XAException.XA_RETRY
ORA 24763	XAException.XAER_PROTO
ORA 24769	XAException.XAER_PROTO
ORA 24770	XAException.XAER_PROTO
ORA 24776	XAException.XAER_PROTO
ORA 2056	XAException.XAER_PROTO
ORA 17448	XAException.XAER_PROTO
ORA 24768	XAException.XAER_PROTO
ORA 24775	XAException.XAER_PROTO
ORA 24761	XAException.XA_RBROLLBACK
ORA 2091	XAException.XA_RBROLLBACK
ORA 2092	XAException.XA_RBROLLBACK
ORA 24780	XAException.XAER_RMERR
All other ORA errors	XAException.XAER_RMFAIL

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37.3.3 XA Error Handling

The following code snippet uses the `OracleXAException` class to process an XA exception:

```
try {
   ...
   ...Perform XA operations...
   ...
} catch(OracleXAException oxae) {
  int oraerr = oxae.getOracleError();
  System.out.println("Error " + oraerr);
}
  catch(XAException xae)
{...Process generic XA exception...}
```

In case the XA operations did not throw an Oracle-specific XA exception, the code drops through to process a generic XA exception.

37.3.4 Oracle XA Optimizations

Oracle JDBC has functionality to improve performance if two or more branches of a distributed transaction use the same database instance, meaning that the `OracleXAResource` instances associated with these branches are associated with the same resource manager.

In such a circumstance, the `prepare` method of only one of these `OracleXAResource` instances will return `XA_OK` or will fail. The rest will return `XA_RDONLY`, even if updates are made. This allows the transaction manager to implicitly join all the transaction branches and commit or roll back, in case of failure, the joined transaction through the `OracleXAResource` instance that returned `XA_OK` or failed.

The transaction manager can use the `OracleXAResource` class `isSameRM` method to determine if two `OracleXAResource` instances are using the same resource manager. This way it can interpret the meaning of `XA_RDONLY` return values.

37.4 About Implementing a Distributed Transaction

This section provides an example of how to implement a distributed transaction using Oracle XA functionality. This section covers the following topics:

- Summary of Imports for Oracle XA
- Oracle XA Code Sample

37.4.1 Summary of Imports for Oracle XA

You must import the following for Oracle XA functionality:

```
import oracle.jdbc.xa.OracleXid;
import oracle.jdbc.xa.OracleXAException;
import oracle.jdbc.pool.*;
import oracle.jdbc.xa.client.*;
import javax.transaction.xa.*;
```

The `oracle.jdbc.pool` package has classes for connection pooling functionality, some of which have XA-related classes as subclasses.

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Alternatively, if the code will run inside Oracle Database and access that database for SQL operations, you must import `oracle.jdbc.xa.server` instead of `oracle.jdbc.xa.client`.

```
import oracle.jdbc.xa.server.*;
```

If your application must access another Oracle Database as part of an XA transaction using the server-side Thin driver, then your code can use the fully qualified names of the `oracle.xa.client` classes.

The `client` and `server` packages each have versions of the `OracleXADataSource`, `OracleXAConnection`, and `OracleXAResource` classes. Abstract versions of these three classes are in the top-level `oracle.jdbc.xa` package.

37.4.2 Oracle XA Code Sample

This example uses a two-phase distributed transaction with two transaction branches, each to a separate database.

Note that for simplicity, this example combines code that would typically be in a middle tier with code that would typically be in a transaction manager, such as the `OracleXAResource` method invocations and the creation of transaction IDs.

For brevity, the specifics of creating transaction IDs and performing SQL operations are not shown here. The complete example is shipped with the product.

This example performs the following sequence:

1. Start transaction branch #1.
2. Start transaction branch #2.
3. Execute DML operations on branch #1.
4. Execute DML operations on branch #2.
5. End transaction branch #1.
6. End transaction branch #2.
7. Prepare branch #1.
8. Prepare branch #2.
9. Commit branch #1.
10. Commit branch #2.

```
// You need to import the java.sql package to use JDBC
import java.sql.*;
import javax.sql.*;
import oracle.jdbc.*;
import oracle.jdbc.pool.*;
import oracle.jdbc.xa.OracleXid;
import oracle.jdbc.xa.OracleXAException;
import oracle.jdbc.xa.client.*;
import javax.transaction.xa.*;

class XA4
{
  public static void main (String args [])
       throws SQLException
  {

    try
```


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```
{
    String URL1 = "jdbc:oracle:oci:@";
    // You can put a database name after the @ sign in the connection URL.
    String URL2 ="jdbc:oracle:thin:@(description=(address=(host=localhost)
                 (protocol=tcp)(port=5521))(connect_data=(service_name=orcl)))";
    // Create first DataSource and get connection
    OracleDataSource ods1 = new OracleDataSource();
    ods1.setURL(URL1);
    ods1.setUser("HR");
    ods1.setPassword("hr");
    Connection conna = ods1.getConnection();

    // Create second DataSource and get connection
    OracleDataSource ods2 = new OracleDataSource();
    ods2.setURL(URL2);
    ods2.setUser("HR");
    ods2.setPassword("hr");
    Connection connb = ods2.getConnection();

    // Prepare a statement to create the table
    Statement stmta = conna.createStatement ();

    // Prepare a statement to create the table
    Statement stmtb = connb.createStatement ();

    try
    {
      // Drop the test table
      stmta.execute ("drop table my_table");
    }
    catch (SQLException e)
    {
      // Ignore an error here
    }

    try
    {
      // Create a test table
      stmta.execute ("create table my_table (col1 int)");
    }
    catch (SQLException e)
    {
      // Ignore an error here too
    }

    try
    {
      // Drop the test table
      stmtb.execute ("drop table my_tab");
    }
    catch (SQLException e)
    {
      // Ignore an error here
    }

    try
    {
      // Create a test table
      stmtb.execute ("create table my_tab (col1 char(30))");
    }
    catch (SQLException e)
    {
```


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```
  // Ignore an error here too
}

// Create XADataSource instances and set properties.
OracleXADataSource oxds1 = new OracleXADataSource();
oxds1.setURL("jdbc:oracle:oci:@");
oxds1.setUser("HR");
oxds1.setPassword("hr");

OracleXADataSource oxds2 = new OracleXADataSource();

oxds2.setURL("jdbc:oracle:thin:@(description=(address=(host=localhost)
          (protocol=tcp)(port=5521))(connect_data=(service_name=orcl)))");
oxds2.setUser("HR");
oxds2.setPassword("hr");

// Get XA connections to the underlying data sources
XAConnection pc1  = oxds1.getXAConnection();
XAConnection pc2  = oxds2.getXAConnection();

// Get the physical connections
Connection conn1 = pc1.getConnection();
Connection conn2 = pc2.getConnection();

// Get the XA resources
XAResource oxar1 = pc1.getXAResource();
XAResource oxar2 = pc2.getXAResource();

// Create the Xids With the Same Global Ids
Xid xid1 = createXid(1);
Xid xid2 = createXid(2);

// Start the Resources
oxar1.start (xid1, XAResource.TMNOFLAGS);
oxar2.start (xid2, XAResource.TMNOFLAGS);

// Execute SQL operations with conn1 and conn2
doSomeWork1 (conn1);
doSomeWork2 (conn2);

// END both the branches -- IMPORTANT
oxar1.end(xid1, XAResource.TMSUCCESS);
oxar2.end(xid2, XAResource.TMSUCCESS);

// Prepare the RMs
int prp1 =  oxar1.prepare (xid1);
int prp2 =  oxar2.prepare (xid2);

System.out.println("Return value of prepare 1 is " + prp1);
System.out.println("Return value of prepare 2 is " + prp2);

boolean do_commit = true;

if (!((prp1 == XAResource.XA_OK) || (prp1 == XAResource.XA_RDONLY)))
   do_commit = false;

if (!((prp2 == XAResource.XA_OK) || (prp2 == XAResource.XA_RDONLY)))
   do_commit = false;

System.out.println("do_commit is " + do_commit);
 System.out.println("Is oxar1 same as oxar2 ? " + oxar1.isSameRM(oxar2));
```


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```
        if (prp1 == XAResource.XA_OK)
          if (do_commit)
             oxar1.commit (xid1, false);
          else
             oxar1.rollback (xid1);

        if (prp2 == XAResource.XA_OK)
          if (do_commit)
             oxar2.commit (xid2, false);
          else
             oxar2.rollback (xid2);

         // Close connections
        conn1.close();
        conn1 = null;
        conn2.close();
        conn2 = null;

        pc1.close();
        pc1 = null;
        pc2.close();
        pc2 = null;

        ResultSet rset = stmta.executeQuery ("select col1 from my_table");
        while (rset.next())
          System.out.println("Col1 is " + rset.getInt(1));

        rset.close();
        rset = null;

        rset = stmtb.executeQuery ("select col1 from my_tab");
        while (rset.next())
          System.out.println("Col1 is " + rset.getString(1));

        rset.close();
        rset = null;

        stmta.close();
        stmta = null;
        stmtb.close();
        stmtb = null;

        conna.close();
        conna = null;
        connb.close();
        connb = null;

      } catch (SQLException sqe)
      {
        sqe.printStackTrace();
      } catch (XAException xae)
      {
        if (xae instanceof OracleXAException) {
          System.out.println("XA Error is " +
                       ((OracleXAException)xae).getXAError());
          System.out.println("SQL Error is " +
                       ((OracleXAException)xae).getOracleError());
        }
      }
    }

    static Xid createXid(int bids)
```


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```
    throws XAException
  {...Create transaction IDs...}

  private static void doSomeWork1 (Connection conn)
   throws SQLException
  {...Execute SQL operations...}

  private static void doSomeWork2 (Connection conn)
   throws SQLException
  {...Execute SQL operations...}
}
```

37.5 Native-XA in Oracle JDBC Drivers

In general, XA commands can be sent to the server in the following ways:

- Through non-native APIs
- Through native APIs

There is a huge performance difference between the two methods of sending XA commands to the server. The use of native APIs provide high performance gains as compared to the use of non-native APIs.

Prior to Oracle Database 10*g*, the Thin driver used non-native APIs to send XA commands to the server because Thin native APIs were not available. The non-native APIs use PL/SQL procedures, so they have the following disadvantages:

- They require different messages on the wire.
- They cause more round-trips to the database.
- They cause more cursors to remain open.
- They damage statement caching by occupying space in the Statement Cache.

Moreover, the implementation of non-native APIs is in the server. So, in order to solve any problem in sending XA commands, it requires a server patch. This creates a major issue because sometimes the patch requires restarting the server.

Starting from Oracle Database 10*g*, the Thin native APIs are available and are used to send XA commands, by default. Native APIs are more than 10 times faster than the non-native ones.

This section covers the following topics:

- OCI Native XA
- Thin Native XA

37.5.1 OCI Native XA

Native XA is enabled through the use of the `tnsEntry` and `nativeXA` properties of the `OracleXADataSource` class.

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> **Note**
>
> Currently, OCI Native XA does not work in a multithreaded environment. The OCI driver uses the C/XA library of Oracle to support distributed transactions, which requires that an XAConnection be obtained for each thread before resuming a global transaction.

Configuration and Installation

On a Solaris or Linux system, you need the `libheteroxa11.so` shared library to enable the Native XA feature. This library must be installed and available in the search path for the Native XA feature to work properly.

On a Microsoft Windows system, you need the `heteroxa11.dll` file to enable the Native XA feature. This file must be installed and available in the Windows DLL path for the Native XA feature to work properly.

Exception Handling

When using the Native XA feature in distributed transactions, it is recommended that the application simply check for `XAException` or `SQLException`, rather than `OracleXAException` or `OracleSQLException`.

> **Note**
>
> The mapping from SQL error codes to standard XA error codes does not apply to the Native XA feature.

Native XA Code Example

The following portion of code shows how to enable the Native XA feature:

```
...
// Create a XADataSource instance
OracleXADataSource oxds = new OracleXADataSource();
oxds.setURL(url);

// Set the nativeXA property to use Native XA feature
oxds.setNativeXA(true);

// Set the tnsEntry property to an older DB as required
oxds.setTNSEntryName("ora805");
...
```

Related Topics

- Features and Properties of Data Sources

37.5.2 Thin Native XA

Like the JDBC OCI driver, the JDBC Thin driver also provides support for Native XA. However, the JDBC Thin driver provides support for Native XA by default. This is unlike the case of the JDBC OCI driver in which the support for Native XA is not enabled by default.

You can disable Native XA by calling `setNativeXA(false)` on the XA data source as follows:

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```
...
// Create a XADataSource instance
OracleXADataSource oxds = new OracleXADataSource();
...
// Disabling Native XA
oxds.setNativeXA(false);
...
```

For example, you may need to disable Native XA as a workaround for a bug in the Native XA code.

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38
Sessionless Transactions

Sessionless Transactions are the transaction that provides you with the flexibility to suspend and resume the transaction during its life cycle.

When you use Sessionless Transactions, you do not need to use a transaction manager when communicating with the Oracle Database (single or multi-instance). The database does all the work of coordinating the transaction for you. Moreover, the database internally coordinates the two-phase commit (2PC) protocol, without the need for any application-side logic.

> **Note**
>
> This feature is supported only from Oracle Database Release 23ai, version 23.6.

38.1 About Sessionless Transactions

A sessionless transaction breaks the coupling between the transaction and the session. Once you start a transaction, it does not need to be tied to a session or connection.

You can free the session or connection, allowing it to be used by another client. Additionally, you do not need a transaction manager to coordinate the XA protocol because the 2-phase commit process and the error recovery process are handled automatically by the database. Therefore, there is no risk of in-doubt transactions and no need for any recovery mechanism. For more information about Sessionless Transactions, its use cases, and benefits, see Developing Applications with Sessionless Transactions in the *Database Development Guide*.

> **Note**
>
> Sessionless Transactions are applicable only to a single database. Do not use Sessionless Transactions to manage transactions that span across multiple resource managers.

38.2 Manage Sessionless Transactions using JDBC APIs

Use the JDBC APIs described in this section to start a new transaction, resume an existing transaction, suspend a transaction, and either commit or roll back the changes to end a transaction.

These APIs are available in the `OracleConnection` interface of the `oracle.jdbc` package. See Oracle® Database JDBC Java API Reference.

The section covers the following topics:

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38.2.1 Start Sessionless Transactions

Use the `startTransaction()` method from the `OracleConnection` interface of the `oracle.jdbc` package to start a sessionless transaction. You may specify a unique Global Transaction ID (GTRID) and timeout for the transaction.

This is an asynchronous call as `startTransaction()` does not perform a round-trip to the database. Instead, Oracle JDBC Thin driver sends a request to start a sessionless transaction when it makes the next round trip to the Oracle Database. The transaction starts only when the server successfully returns the call.

To start a sessionless transaction, complete the following tasks:

1. (Optional) Provide a unique identifier called global transaction ID (GTRID) for every sessionless transaction. Specify the unique value as a byte array which has the size between 1 to 64 bytes.

   If you do not specify a value, the Oracle JDBC Thin driver generates a unique value as the GTRID. You will use the GTRID to manage a transaction from start to end.

2. (Optional) Decide the `timeout`, which specifies the maximum duration for which a sessionless transaction can stay in the `suspended` state. If a suspended sessionless transaction is not resumed within the specified duration, Oracle Database cancels the transaction.

   Consider the following points while specifying the timeout.

   - If you specify a very high value, the transaction may hold database resources, such as locked rows, for the specified duration.
   - If you specify a very low value, for example 0, the transaction is canceled as soon as a sessionless transaction is suspended and released.
   - The default value is 60 seconds.

3. Call the `startTransaction()` method of the `OracleConnection` interface in one of the following ways.

   - This API starts a sessionless transaction with the default timeout of 60 seconds. The driver creates a unique GTRID for the transaction.

     ```
     public byte[] startTransaction() throws SQLException;
     ```

   - This API starts a sessionless transaction with the specified timeout. The driver creates a unique GTRID for the transaction.

     ```
     public byte[] startTransaction(int timeout) throws SQLException;
     ```

   - This API starts a sessionless transaction with the GTRID that you specify and the default timeout of 60 seconds.

     ```
     public void startTransaction(byte[] GTRID) throws SQLException;
     ```

   - This API starts a sessionless transaction with the GTRID and timeout that you specify.

     ```
     public void startTransaction(byte[] GTRID, int timeout) throws
     SQLException;
     ```


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When a new sessionless transaction starts, it is in the active state. The GTRID for a transaction must be unique. If an active sessionless transaction already exists when you make a request to start a new sessionless transaction, the Oracle Database suspends the existing transaction and starts a new sessionless transaction based on your request.

38.2.2 Retrieve GTRID

Retrieves the GTRID of a sessionless transaction that is currently in the active state.

Sessionless Transactions are identified by a unique identifier called global transaction ID (GTRID). GTRID is used to manage a transaction from start to end.

- The following API retrieves the GTRID of a sessionless transaction that is currently in the active state.

  ```
  byte[] getTransactionId() throwsSQLException;
  ```

  It returns null, if there is no sessionless transaction in the active state.

Example

The retrieved GTRID reflects the state of the sessionless transaction locally and not its state in the server. Let's understand this with the following scenario, where `startTransaction()` is an asynchronous call and it does not perform a round-trip to the database. Instead, Oracle JDBC Thin driver sends the request to start a sessionless transaction when it makes the next round trip to the Oracle Database. The transaction starts only when the server successfully returns the call.

```
...
conn.startTransaction();
byte[] gtrid = getTransactionId();
...
```

Even though the transaction has not actually started on the server until the next round-trip, `getTransactionId()` returns the value of the GTRID generated by the Oracle JDBC Thin drivers.

38.2.3 Suspend Sessionless Transactions

Suspends an active sessionless transaction.

- Call a method to suspend a transaction in one of the following ways.
  - Use the following API to synchronously suspend an active sessionless transaction. This makes a round trip to the Oracle Database and immediately suspends a sessionless transaction.

    ```
    void suspendTransactionImmediately() throws SQLException;
    ```

  - Use the following API to asynchronously suspend an active sessionless transaction. This is an asynchronous call as `suspendTransaction()` does not perform a round-trip to the database. Instead, Oracle JDBC Thin driver sends a request to suspend a

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sessionless transaction when it makes the next round trip to the Oracle Database. The transaction is suspended only when the server successfully returns the call.

```
void suspendTransaction() throws SQLException;
```

- Use the following API to suspend an active sessionless transaction when you know about the last operation that is performed on the database before suspending the transaction. This is useful because it allows you to reduce the number of roundtrips to the server which provides better performance. However, note that if either `executeUpdate()` or `suspend()` operations throw an exception, both operations fail.

```
void executeUpdateAndSuspend() throwsSQLException;
```

If there are no sessionless transactions in the active state, then no operation is performed as there are no active transactions to suspend. This request is ignored, and no error message is returned.

38.2.4 Resume Sessionless Transactions

Resumes a suspended sessionless transaction.

If a sessionless transaction is in the suspended state when you send the request to resume a transaction, it resumes the transaction. The sessionless transaction is resumed on the instance where you have requested the transaction to be resumed. After a sessionless transaction is resumed, it is in the active state.

When you send a request to resume a transaction in a session, if a different sessionless transaction is already active in that session, Oracle Database first attempts to suspend that transaction and then proceeds to perform the resume operation.

This is an asynchronous call as `resumeTransaction()` does not perform a round-trip to the database. Instead, Oracle JDBC Thin driver sends a request to resume a sessionless transaction when it makes the next round trip to the Oracle Database. The transaction resumes only when the server successfully returns the call.

To resume a suspended sessionless transaction:

1. Identify the GTRID of the sessionless transaction that you want to resume.
2. (Optional) Decide the `timeout`, which specifies the maximum duration for which a sessionless transaction can stay in the `suspended` state. If a suspended sessionless transaction is not resumed within the specified duration, Oracle Database cancels the transaction.

   Consider the following points while specifying the timeout.

   - If you specify a very high value, the transaction may hold database resources, such as locked rows, for the specified duration.
   - If you specify a very low value, for example 0, the transaction is canceled as soon as a sessionless transaction is suspended and released.
   - The default value is 60 seconds.
3. Call the `resumeTransaction()` method, which is available in the `OracleConnection` interface, in one of the following ways. You must specify the GTRID of the transaction that you want to resume.

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- Use the following API to resume a sessionless transaction while using the default timeout of 60 seconds.

```
void resumeTransaction(byte[] GTRID) throws SQLException;
```

- Use the following API to resume a sessionless transaction while using the specified timeout.

```
void resumeTransaction(byte[] GTRID, int timeout) throws SQLException;
```

38.2.5 Example

This section provides an example to modify an existing application code to use the sessionless transaction feature.

Let's consider that an application wants to avoid locking sessions while working on a transaction that starts, makes some updates, and then makes multiple calls to other services. After it gets the results from other services, it continues working on the transaction. Example code is provided below for your reference to compare the changes required when you use sessionless transaction.

Existing Sample Code Which Does Not Use Sessionless Transactions

The following code provides a sample implementation of such an application that does not use Sessionless Transactions.

```
PoolDataSource ds;

Connection conn = ds.getConnection();
conn.setAutoCommit(false);
// update database

// Fetch some data from other services(takes a while)

// do more updates on the database

conn.commit();
conn.close();
```

Optimized Sample Code to Use Sessionless Transactions

The following sample code provides the optimized sample code to use Sessionless Transactions. To manage Sessionless Transactions using JDBC APIs, which are available in the `OracleConnection` interface of the `oracle.jdbc` package, you must type cast the connection object to `OracleConnection` as shown in the following sample code.

```
import oracle.jdbc.*;

PoolDataSource ds;

// GTRID is the unique identifier for a session.
byte[] gtrid;

// Acquire a session on instance 1.
```


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```
Connection conn = ds.getConnection();
conn.setAutoCommit(false);

// Start a sessionless transaction with a unique identifier on instance 1
gtrid = ((OracleConnection)conn).startTransaction();

// Update database
((OracleConnection)conn).suspendTransaction();
conn.close();

// Fetch some data from other services, which may take some time
Connection conn2 = ds.getConnection();
conn2.setAutoCommit(false);

// Resume the sessionless transaction using the unique identifier,
// that you had defined earlier, on instance 2.
(OracleConnection(conn2)).resumeTransaction(gtrid);

// do more updates on the database
conn2.commit();

conn2.close();
```

38.3 Manage Sessionless Transactions with Existing XA APIs

This section provides information about how you can manage Sessionless Transactions using the existing `XAResource` interface.

Sessionless Transactions are compatible with the APIs used for XA transactions. Set the `oracle.jdbc.XAThroughSessionlessTransactions` system property to `true` when you want the Oracle JDBC Thin driver to process sessionless transactions using XA APIs. The driver converts the XID provided by the transaction manager to GTRID, a unique identifier for a sessionless transaction. By default, `oracle.jdbc.XAThroughSessionlessTransactions` is set to `false`.

Limitations:

- You can use sessionless transaction only when your application connects to a single Oracle Database running on one server or in a RAC.
- You can't have other resources managers, for example a different database, involved in a sessionless transaction.

Before running your application, set the following system property value using the command line when you want to use XA APIs to manage sessionless transactions.

- Use the `-D` option of the java command to set the `oracle.jdbc.XAThroughSessionlessTransactions` system property to `true` using the command line.

  ```
  java -Doracle.jdbc.XAThroughSessionlessTransactions=true
  ```

So, if your existing application code uses XA transactions and implements the `XAResource` interface, then you can use the same code manage a sessionless transaction. When you set the `oracle.jdbc.XAThroughSessionlessTransactions` property value, behavior of the methods in the `XAResource` interface change as described in the following table and the

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transaction is treated as a sessionless transaction. In this way, you can benefit the from the performance improvements of sessionless transaction without having to change a lot in the code of an existing application.

Method	Description
`xaResource.start(xid, XAResource.TMNOFLAGS);`	Starts a sessionless transaction.
`xaResource.start(xid, XAResource.TMRESUME);`	Resumes a sessionless transaction.
`(OracleXAResource).suspend(xid);`	Suspends a sessionless transaction.
`xaResource.end(xid1, XAResource.TMSUSPEND);`	Suspends a sessionless transaction.
`xaResource.end(xid2, XAResource.TMSUCCESS);`	Suspends a sessionless transaction.
`xaResource.setTransactionTimeout(seconds);`	Sets the transaction timeout value in seconds.
`xaResource.commit(xid, true);`	Commits a sessionless transaction. It first resumes the transaction, and then commits the transaction.
`xaResource.rollback(xid);`	Rolls back a sessionless transaction. It first resumes the transaction, and then rolls back the transaction.
`xaResource.join(xid);`	No operation is performed in case of sessionless transaction.
`xaResource.prepare(xid);`	No operation is performed in case of sessionless transaction.
`xaResource.recover(XAResource.TMSTARTRSCAN);`	XA recover is **not supported** with sessionless transactions. This throws an exception.
`xaResource.forget(xid);`	No operation is performed in case of sessionless transaction.
`xaResource1.isSameRM(xaResource2);`	No operation is performed in case of sessionless transaction.

For more information about the `XAResource` interface, see https://docs.oracle.com/javase/8/docs/api/javax/transaction/xa/XAResource.html.

You can also manage Sessionless Transactions in a client application using JDBC APIs defined in `OracleConnection` interface. See Manage Sessionless Transactions using JDBC APIs.

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Part VIII
Manageability

This part discusses the database management and diagnosability support in Oracle Java Database Connectivity (JDBC) drivers.

Part VIII contains the following chapters:

- Database Administration
- Diagnosability in JDBC
- JDBC DMS Metrics

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39
Database Administration

This chapter discusses the database administration methods introduced in Oracle Database 11*g* Release 1. This chapter contains the following sections:

- Using the Database Administration Methods
- Using the startup Method
- Using the shutdown Method
- A Complete Example

39.1 Using the Database Administration Methods

Starting from Oracle Database 11*g* Release 1, two JDBC methods, `startup` and `shutdown`, has been added in the `oracle.jdbc.OracleConnection` interface, which enable you to start up and shut down an Oracle Database instance. This is similar to the way you would start up or shut down a database instance from SQL*Plus.

To use the `startup` and `shutdown` methods, you must:

- Have a dedicated connection to the server. You cannot be connected to a shared server through a dispatcher.
- Be connected as `SYSDBA` or `SYSOPER`. To connect as `SYSDBA` or `SYSOPER` with Oracle JDBC drivers, you need to set the `INTERNAL_LOGON` connection property accordingly.

To log on as `SYSDBA` with the JDBC Thin driver you must configure the server to use the password file. For example, to configure `system/manager` to connect as `SYSDBA` with the JDBC Thin driver, perform the following:

1. From the command line, type:

```
orapwd file=$ORACLE_HOME/dbs/orapw entries=5
Enter password: password
```

2. Connect to database as `SYSDBA` and run the following commands from SQL*Plus:

```
GRANT SYSDBA TO system;
PASSWORD system
       Changing password for system
       New password: password
       Retype new password: password
```

3. Edit `init.ora` and add the following line:

```
REMOTE_LOGIN_PASSWORDFILE=EXCLUSIVE
```

4. Restart the database instance.

As opposed to the JDBC Thin driver, the JDBC OCI driver can connect as `SYSDBA` or `SYSOPER` locally without specifying a password file on the server.

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39.2 Using the startup Method

To start a database instance using the `startup` method, the application must first connect to the database as a `SYSDBA` or `SYSOPER` in the `PRELIM_AUTH` mode, which is the only connection mode that is permitted when the database is down. You can do this by setting the connection property `PRELIM_AUTH` to `true`. In the `PRELIM_AUTH` mode, you can *only* start up a database instance that is down. You *cannot* run any SQL statements in this mode.

Example

The following code snippet shows how to start up a database instance that is down:

```
 OracleDataSource ds = new OracleDataSource();
    Properties prop = new Properties();
    prop.setProperty("user","sys");
    prop.setProperty("password","manager");
    prop.setProperty("internal_logon","sysdba");
    prop.setProperty("prelim_auth","true");
    ds.setConnectionProperties(prop);
    ds.setURL("jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)(HOST=XYZ.com)
(PORT=5221))"
+ "(CONNECT_DATA=(SERVICE_NAME=rdbms.devplmt.XYZ.com)))");
    OracleConnection conn = (OracleConnection)ds.getConnection();
    conn.startup(OracleConnection.DatabaseStartupMode.NO_RESTRICTION);
    conn.close();
```

> **Note**
>
> The `startup` method will start up the database using the server parameter file. Oracle JDBC drivers do *not* support database startup using the client parameter file.

39.2.1 Database Startup Options

The `startup` method takes a parameter that specifies the database startup option.

The following table lists the supported database startup options. These options are defined in the `oracle.jdbc.OracleConnection.DatabaseStartupMode` class.

Table 39-1 Supported Database Startup Options

Option	Description
`FORCE`	Shuts down the current instance of the database, if any, in the `ABORT` mode, before starting a new instance.
`NO_RESTRICTION`	Starts up the database with no restrictions.
`RESTRICT`	Starts up the database and allows database access only to users with both the `CREATE SESSION` and `RESTRICTED SESSION` privileges, typically, the DBA.

The `startup` method only starts up a database instance. It neither mounts it nor opens it. For mounting and opening the database instance, you have to reconnect as `SYSDBA` or `SYSOPER`, without the `PRELIM_AUTH` mode.

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Example

The following code snippet shows how to mount and open a database instance:

```
OracleDataSource ds1 = new OracleDataSource();
Properties prop1 = new Properties();
prop1.setProperty("user","sys");
prop1.setProperty("password","manager");
prop1.setProperty("internal_logon","sysdba");
ds1.setConnectionProperties(prop1);
ds1.setURL(DB_URL);
OracleConnection conn1 = (OracleConnection)ds1.getConnection();
Statement stmt = conn1.createStatement();
stmt.executeUpdate("ALTER DATABASE MOUNT");
stmt.executeUpdate("ALTER DATABASE OPEN");
```

39.3 Using the shutdown Method

The `shutdown` method enables you to shut down an Oracle Database instance. To use this method, you must be connected to the database as a `SYSDBA` or `SYSOPER`.

Example

The following code snippet shows how to shut down a database instance:

```
    OracleDataSource ds2 = new OracleDataSource();
...
    OracleConnection conn2 = (OracleConnection)ds2.getConnection();
    conn2.shutdown(OracleConnection.DatabaseShutdownMode.IMMEDIATE);
    Statement stmt1 = conn2.createStatement();
    stmt1.executeUpdate("ALTER DATABASE CLOSE NORMAL");
    stmt1.executeUpdate("ALTER DATABASE DISMOUNT");
    stmt1.close();
    conn2.shutdown(OracleConnection.DatabaseShutdownMode.FINAL);
    conn2.close();
```

39.3.1 Database Shutdown Options

Like the `startup` method, the `shutdown` method also takes a parameter. In this case, the parameter specifies the database shutdown option. Table 39-2 lists the supported database shutdown options. These options are defined in the `oracle.jdbc.OracleConnection.DatabaseShutdownMode` class.

Table 39-2 Supported Database Shutdown Options

Option	Description
`ABORT`	Does not wait for current calls to complete or users to disconnect from the database.
`CONNECT`	Refuses any new connection and waits for existing connection to end.
`FINAL`	Shuts down the database.
`IMMEDIATE`	Does not wait for current calls to complete or users to disconnect from the database.
`TRANSACTIONAL`	Refuses new transactions and waits for active transactions to end.
`TRANSACTIONAL_LOCAL`	Refuses new local transactions and waits for active local transactions to end.

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For shutdown options other than ABORT and FINAL, you must call the shutdown method again with the FINAL option to actually shut down the database.

> **Note**
>
> The shutdown(DatabaseShutdownMode.FINAL) method must be preceded by another call to the shutdown method with one of the following options: CONNECT, TRANSACTIONAL, TRANSACTIONAL_LOCAL, or IMMEDIATE. Otherwise, the call hangs.

39.3.2 Standard Database Shutdown Process

A standard way to shut down the database is as follows:

1. Initiate shutdown by prohibiting further connections or transactions in the database. The shut down option can be either CONNECT, TRANSACTIONAL, TRANSACTIONAL_LOCAL, or IMMEDIATE.
2. Dismount and close the database by calling the appropriate ALTER DATABASE command.
3. Finish shutdown using the FINAL option.

In special circumstances to shut down the database as fast as possible, the ABORT option can be used. This is the equivalent to SHUTDOWN ABORT in SQL*Plus.

39.4 A Complete Example

Example 39-1 illustrates the use of the startup and shutdown methods.

Example 39-1 Database Startup and Shutdown

```
import java.sql.Statement;
import java.util.Properties;
import oracle.jdbc.OracleConnection;
import oracle.jdbc.pool.OracleDataSource;
/**
 * To logon as sysdba, you need to create a password file for user "sys":
 *   orapwd file=/path/orapw password=password entries=300
 * and add the following setting in init.ora:
 *   REMOTE_LOGIN_PASSWORDFILE=EXCLUSIVE
 * then restart the database.
 */
public class DBStartup
{
  static final String DB_URL = "jdbc:oracle:thin:@(DESCRIPTION=(ADDRESS=(PROTOCOL=tcp)
(HOST=localhost)(PORT=5221))"
+ "(CONNECT_DATA=(SERVICE_NAME=rdbms.devplmt.XYZ.com)))";

  public static void main(String[] argv) throws Exception
  {
// Starting up the database:
    OracleDataSource ds = new OracleDataSource();
    Properties prop = new Properties();
    prop.setProperty("user","sys");
    prop.setProperty("password","manager");
    prop.setProperty("internal_logon","sysdba");
    prop.setProperty("prelim_auth","true");
    ds.setConnectionProperties(prop);
```


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```
    ds.setURL(DB_URL);
    OracleConnection conn = (OracleConnection)ds.getConnection();
    conn.startup(OracleConnection.DatabaseStartupMode.NO_RESTRICTION);
    conn.close();

// Mounting and opening the database
    OracleDataSource ds1 = new OracleDataSource();
    Properties prop1 = new Properties();
    prop1.setProperty("user","sys");
    prop1.setProperty("password","manager");
    prop1.setProperty("internal_logon","sysdba");
    ds1.setConnectionProperties(prop1);
    ds1.setURL(DB_URL);
    OracleConnection conn1 = (OracleConnection)ds1.getConnection();
    Statement stmt = conn1.createStatement();
    stmt.executeUpdate("ALTER DATABASE MOUNT");
    stmt.executeUpdate("ALTER DATABASE OPEN");
    stmt.close();
    conn1.close();

// Shutting down the database
    OracleDataSource ds2 = new OracleDataSource();
    Properties prop = new Properties();
    prop.setProperty("user","sys");
    prop.setProperty("password","manager");
    prop.setProperty("internal_logon","sysdba");
    ds2.setConnectionProperties(prop);
    ds2.setURL(DB_URL);
    OracleConnection conn2 = (OracleConnection)ds2.getConnection();
    conn2.shutdown(OracleConnection.DatabaseShutdownMode.IMMEDIATE);
    Statement stmt1 = conn2.createStatement();
    stmt1.executeUpdate("ALTER DATABASE CLOSE NORMAL");
    stmt1.executeUpdate("ALTER DATABASE DISMOUNT");
    stmt1.close();
    conn2.shutdown(OracleConnection.DatabaseShutdownMode.FINAL);
    conn2.close();
  }
}
```


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40
Diagnosability in JDBC

The JDBC diagnosability feature is enhanced in this release to make it more user-friendly.

The enhancement also facilitates the use of the JDBC drivers in the Oracle Cloud Infrastructure (OCI) environment because unlike the On-Premises users, the Cloud users do not have absolute access to the system. The enhanced diagnosability feature provides diagnostic capabilities that are accessible and configurable in the Cloud environment.

40.1 Overview of JDBC Diagnosability

JDBC diagnosability feature is a client-only feature. Like in previous releases, it uses the Java Util Logging framework. It does not work with the Server-side Thin driver or the Server-side internal driver.

In the previous releases, the debug `JAR` files are used for logging purposes. These files are indicated with a `_g` in the file name, for example, `ojdbc8_g.jar` or `ojdbc11_g.jar`, and must be included in the `CLASSPATH`. The enhanced diagnosability feature in the Database 23ai Release, eliminates the need to use the debug `JAR` files, and also the need to switch between the regular `JAR` files and the debug `JAR` files. Now, the regular `JAR` files include logging capabilities, which can be turned on with the following property:

```
oracle.jdbc.diagnostic.enableLogging=true
```

This property can be set either through a Java System property (using the `-D` option) or through a `DataSource` property.

The logging configuration file can be configured in the following way:

```
-Djava.util.logging.config.file=./logging.config
```

For example, the following logging configuration file turns on the JDBC logging in the console with the `OracleSimpleFormatter`:

```
handlers = java.util.logging.ConsoleHandler
oracle.jdbc.level = ALL
java.util.logging.ConsoleHandler.level = ALL
java.util.logging.ConsoleHandler.formatter =
oracle.jdbc.diagnostics.OracleSimpleFormatter
```

Logging can be enabled dynamically through the `com.oracle.jdbc.diagnosability` JDBC MBean. This MBean defines multiple operations such as `enableLogging`, `disableLogging`, or `enableLoggingByConnectionIdPrefix`, and so on. All these operations can also be called programmatically by invoking the relevant operation. For example:

```
void enableLogging(boolean enable) {
  try {
    Object loader = oracle.jdbc.driver.OracleDriver.class.getClassLoader();
```


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```
    String loaderName =
            (loader == null ? "nullLoader" : loader.getClass().getName());
    String name = loaderName + "@" +
                      Integer.toHexString(
                              (loader == null ? 0 : loader.hashCode())
                      // If the same class loader loads the JDBC drivers
multiple times, then each
                      // subsequent MBean increments the value of the
loader.hashCode() method, so as to
                      // create a unique name. It may be problematic to
identify which MBean is
                      // associated with which JDBC driver instance.
                      );
    javax.management.ObjectName diagnosticMBeanObjectName = new
javax.management.ObjectName("com.oracle.jdbc:type=diagnosability,name=" +
name);

    // get the MBean server
    javax.management.MBeanServer mbs =
java.lang.management.ManagementFactory.getPlatformMBeanServer();

    // find out if logging is enabled or not
    System.out.println("LoggingEnabled = " +
mbs.getAttribute(diagnosticMBeanObjectName, "LoggingEnabled"));

    // enable logging
    if(enable)
      mbs.invoke(diagnosticMBeanObjectName, "enableLogging", null, null);
    else
      mbs.invoke(diagnosticMBeanObjectName, "disableLogging", null, null);
  } catch (Exception e) {
    e.printStackTrace();
  }
}
```

Features of JDBC Diagnosability

The improved JDBC diagnosability feature is built upon the following features of Oracle Database:

- **Observability**: It enables Java developers to access summary information about the execution and performance of JDBC.
- **Diagnosability**: It records critical execution state in the event of a failure. Ideally, such a state is sufficient to diagnose the first occurrence of a failure and come up with a resolution of the problem causing the failure. You must balance the amount of state information recorded against the cost of recording such a state.
- **Execution Trace**: It records the execution sequence details. As execution trace has significant cost involved, you must enable it only in limited contexts.

Each diagnosability feature has two modes, public and sensitive. In the public mode, these features do not record or persist sensitive information. This severely limits the amount of information captured, and reduces the effectiveness of the diagnosability features. In the sensitive mode, these features record and persist sensitive information. You must be a privileged user for permitting the sensitive mode.

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The sensitive mode is controlled by two switches, one for enabling and one for permitting. The sensitive mode for each of the diagnosability feature is permitted by setting the appropriate Java command-line switch. If the `permit` switch is not set on the Java command line as a Java System property, then the sensitive mode cannot be enabled. After permitting the sensitive mode, you must enable it, as shown in the following example:

```
-Doracle.jdbc.diagnostic.permitSensitiveDiagnostics=true
-Doracle.jdbc.diagnostic.enableSensitiveDiagnostics=true
```

> **Note**
>
> - Permitting the sensitive mode does not automatically enable it. Attempting to enable sensitive mode, when not permitted, causes an irrecoverable error.
> - Similarly to enabling logging, enabling the sensitive mode can be done dynamically through the MBean.
> - When the sensitive mode is enabled, the SQL text appears in the logs, but not the parameter data.

Examples

The following code snippets show how to configure the logging configuration file:

Example 40-1 Configuring the Logging File

```
handlers = java.util.logging.ConsoleHandler
oracle.jdbc.level = FINEST
java.util.logging.ConsoleHandler.level = FINEST
java.util.logging.ConsoleHandler.formatter =
oracle.jdbc.diagnostics.OracleSimpleFormatter
```

Example 40-2 Configuring the Logging File (detailed)

```
handlers=java.util.logging.FileHandler
java.util.logging.FileHandler.level = FINEST
java.util.logging.FileHandler.formatter =
oracle.jdbc.diagnostics.OracleSimpleFormatter
java.util.logging.FileHandler.pattern = client.log
java.util.logging.FileHandler.limit = 1000000000
java.util.logging.FileHandler.count = 1000
oracle.ucp.level=FINEST
oracle.jdbc.level=FINEST
```

40.2 The Diagnose First Failure Feature

One of the major features of the enhanced diagnosability is the Diagnose First Failure feature.

When you enable this feature, it diagnoses the first occurrence of a failure, and the most critical trace information is captured in memory. As that memory fills, the oldest trace records are overwritten, and are subsequently dumped into `java.util.logging`, when signaled. One of the following can signal the dumping of the trace records:

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- Occurrence of an error in the connection
- Client application code calling an API
- An MBean

This feature captures only the most critical information, that is, the extent of information that provides a reasonable chance of diagnosing the most likely problems. In the public mode, this information is severely restricted, so that any sensitive information is omitted. In the sensitive mode, this information includes the entire network conversation.

This feature is enabled by default. You can disable it either by setting the `CONNECTION_PROPERTY_ENABLE_DIAGNOSE_FIRST_FAILURE` property to `FALSE` or through the `DiagnosticMBeans` interface.

See Also

Oracle Database JDBC Java API Reference

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41

JDBC DMS Metrics

DMS metrics are used to measure the performance of application components.

This chapter discusses the following topics:

- Overview of JDBC DMS Metrics
- About Determining the Type of Metric to Be Generated
- About Generating the SQLText Metric
- About Accessing DMS Metrics Using JMX

Note

There is another kind of metrics called end-to-end metrics. End-to-end metrics are used for tagging application activity from the entry into the application code through JDBC to the database and back.

JDBC supports the following end-to-end metrics:

- `Action`
- `ClientId`
- `ExecutionContextId`
- `Module`
- `State`

For earlier releases, to work with the preceding metrics, you could use the `setEndToEndMetrics` and `getEndToEndMetrics` methods of the `oracle.jdbc.OracleConnection` interface. However, starting from Oracle Database 12*c* Release 1 (12.1), these methods have been deprecated. Oracle recommends to use the `setClientInfo` and `getClientInfo` methods instead of the `setEndToEndMetrics` and `getEndToEndMetrics` methods.

In Oracle Database 10*g*, Oracle Java Database Connectivity (JDBC) supports end-to-end metrics. In Oracle Database 12*c* Release 1 (12.1), an application can set the end-to-end metrics directly only when it does not use a DMS-enabled JAR files. But, if the application uses a DMS-enabled JAR file, the end-to-end metrics can be set only through DMS.

Warning

Oracle strongly recommends using DMS metrics, if the application uses a DMS-enabled JAR file.

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> **See Also**
>
> *Oracle Database JDBC Java API Reference* for more information about end-to-end metrics

41.1 Overview of JDBC DMS Metrics

DMS metrics enable application and system developers to measure and export customized performance metrics for specific software components.

Starting with Oracle Database 23ai Release, Oracle does not provide the `ojdbc<n>dms.jar` and `ojdbc<n>dms_g.jar` files, for example, the `ojdbc8dms.jar`, `ojdbc8dms_g.jar`, `ojdbc11dms.jar`, `ojdbcdms_g.jar` files. This release includes only the `ojdbc8.jar`, `ojdbc11.jar`, and `ojdbc17.jar` files, which acts as the `ojdbc<n>dms.jar` file, when the `dms.jar` file is present in the `CLASSPATH` environment variable.

The metrics generated in Oracle Database Release 23ai are different from the metrics generated for the earlier versions of Oracle JDBC as it makes no attempt to retain compatibility with earlier versions. There are also no compatibility modes. A system that is dependent on the exact details of the DMS metrics generated by earlier versions of JDBC may have unexpected behavior, when processing the metrics generated by Oracle JDBC 23ai. This is by design and cannot be changed.

Statement metrics can be reported in a consolidated manner for all statements in a connection or individually for each statement. All DMS metrics, except those related to individual statements, are enabled at all times.

> **Note**
>
> You can enable or disable the `SQLText` statement metric. It is disabled by default. If enabled, it is enabled for all the statements. See About Generating the SQLText Metric for more information.

41.2 About Determining the Type of Metric to Be Generated

To determine whether to use consolidated or individual metrics, JDBC checks the DMSConsole sensor weight. If the sensor weight is less than or equal to `DMSConsole.NORMAL`, then JDBC generates consolidated statement metrics. If the sensor weight is greater than `DMSConsole.NORMAL`, then JDBC generates individual statement metrics.

JDBC checks the DMSConsole sensor weight when creating a Prepared or Callable statement and depending on the sensor weight at the time the statement is created, the metrics are generated. Changing the value of the sensor weight, after the statement has been created, does not cause a statement to switch between consolidated and individual metrics.

> **Note**
>
> In the presence of Statement caching, it may appear that changing sensor weight has no impact as statements are retrieved from the cache rather than created anew.

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There is only one list of statement metrics that is generated for both consolidated and individual statement metrics. The only difference between these two lists is the aggregation of the statements. When individual statement metrics are generated, one set of metrics is generated for each distinct statement object created by the JDBC driver. On the other hand, when consolidated statement metrics are generated, all statements created by a given connection use the same set of statement metrics.

For example, consider an 'execute' phase event. If individual statement metrics are used, then each statement created will have a distinct 'execute' phase event. So, from two such statements, it will be possible to distinguish the execution statistics for the two separate statements. If one has an execution time of 1 second and the other an execution time of 3 seconds, then there will be two distinct 'execute' phase events, one with a total time and average of 1 second and the other with a total time and average of 3 seconds. But, if consolidated statement metrics are used, all statements will use the single 'execute' phase event common to the connection. So, from two such statements created by the same connection, it will not be possible to distinguish the execution statistics for the two statements. If one has an execution time of 1 second and the other an execution time of 3 seconds, then the common 'execute' phase event will report a total execution time of 4 seconds and an average of 2 seconds.

41.3 About Generating the SQLText Metric

Depending on the version of DMS, there are two mechanisms for determining the generating of the `SQLText` statement metrics:

- If the 12*c* version of the DMS JAR file is present in the `CLASSPATH` environment variable, then JDBC checks the DMS update SQL text flag. If this flag is `true`, then the `SQLText` metric is updated.
- If the 12*c* version of the DMS JAR file is not present in the `CLASSPATH` environment variable, then JDBC uses the value of the `DMSStatementMetrics` connection property. If this statement property is `true`, then the `SQLText` metric is updated. The default value of this connection property is `false`.

The generation of the `SQLText` metric is independent of the type of statement metrics used, that is, it does not matter whether you are using individual statement metrics or consolidated statement metrics.

41.4 About Accessing DMS Metrics Using JMX

JMX (Java Management Extensions) is a Java technology that supplies tools for managing and monitoring applications, system objects, devices, service-oriented networks, and the JVM (Java Virtual Machine). You can easily access DMS metrics at run time using a management application that supports JMX. For more information about using JMX to access DMS data, go to the following URL http://www.oracle.com/technetwork/middleware/toplink/overview/index.html

See Also

Oracle Database Java Developer's Guide for more information about JMX

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Part IX
Appendixes

This part consists of appendixes that discuss Java Database Connectivity (JDBC) reference information, tips for coding JDBC applications, JDBC error messages, and troubleshooting JDBC applications.

Part IX contains the following appendixes:

- JDBC Reference Information
- Oracle RAC Fast Application Notification
- JDBC Coding Tips
- JDBC Error Messages
- Troubleshooting

A

JDBC Reference Information

This appendix contains detailed Java Database Connectivity (JDBC) reference information, including the following topics:

- Supported SQL-JDBC Data Type Mappings
- Supported SQL and PL/SQL Data Types
- About Using PL/SQL Types
- Using Embedded JDBC Escape Syntax
- Oracle JDBC Notes and Limitations

A.1 Supported SQL-JDBC Data Type Mappings

This section lists all the possible Java types to which a given SQL data type can have a valid mapping.

Oracle JDBC drivers will support these nondefault mappings. For example, to materialize SQL `CHAR` data in an `oracle.sql.CHAR` object, use the `getCHAR` method. To materialize it as a `java.math.BigDecimal` object, use the `getBigDecimal` method.

> **Note**
>
> The classes, where `oracle.jdbc.OracleData` appears in italic, can be generated by Oracle JVM Web Services Call-Out Utility.

Table A-1 Valid SQL Data Type-Java Class Mappings

SQL data type	Java types
`BOOLEAN`	`boolean`, `java.lang.Boolean`, `oracle.sql.BOOLEAN`
`CHAR`, `VARCHAR2`, `LONG`	`java.lang.String` `oracle.sql.CHAR`

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Table A-1 (Cont.) Valid SQL Data Type-Java Class Mappings

SQL data type	Java types
NUMBER	boolean
	char
	byte
	short
	int
	long
	float
	double
	java.lang.Byte
	java.lang.Short
	java.lang.Integer
	java.lang.Long
	java.lang.Float
	java.lang.Double
	java.math.BigDecimal
	oracle.sql.NUMBER
BINARY_INTEGER	boolean
	char
	byte
	short
	int
	long
BINARY_FLOAT	oracle.sql.BINARY_FLOAT
BINARY_DOUBLE	oracle.sql.BINARY_DOUBLE
DATE	oracle.sql.DATE
RAW	oracle.sql.RAW
BLOB	oracle.jdbc.OracleBlob
CLOB	oracle.jdbc.OracleClob
BFILE	oracle.sql.BFILE
ROWID	oracle.sql.ROWID
TIMESTAMP	oracle.sql.TIMESTAMP
TIMESTAMP WITH TIME ZONE	oracle.sql.TIMESTAMPTZ
TIMESTAMP WITH LOCAL TIME ZONE	oracle.sql.TIMESTAMPLTZ
ref cursor	java.sql.ResultSet
user defined named types, abstract data types	oracle.jdbc.OracleStruct
opaque named types	oracle.jdbc.OracleOpaque
nested tables and VARRAY named types	oracle.jdbc.OracleArray
references to named types	oracle.jdbc.OracleRef

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> **Note**
>
> - The type `UROWID` is not supported.
> - The `oracle.sql.Datum` class is abstract. The value passed to a parameter of type `oracle.sql.Datum` must be of the Java type corresponding to the underlying SQL type. Likewise, the value returned by a method with return type `oracle.sql.Datum` must be of the Java type corresponding to the underlying SQL type.

A.2 Supported SQL and PL/SQL Data Types

The tables in this section list SQL and PL/SQL data types, and Oracle JDBC driver support for them. The following table describes Oracle JDBC driver support for SQL data types.

Table A-2 Support for SQL Data Types

SQL Data Type	Supported by JDBC Drivers?
BFILE	yes
BLOB	yes
CHAR	yes
CLOB	yes
DATE	yes
NCHAR	no[1]
NCHAR VARYING	no
NUMBER	yes
NVARCHAR2	yes[2]
RAW	yes
REF	yes
ROWID	yes
UROWID	no
VARCHAR2	yes

1 The NCHAR type is supported indirectly. There is no corresponding java.sql.Types type, but if your application calls the formOfUse(NCHAR) method, then this type can be accessed.
2 In JSE 6, the NVARCHAR2 type is supported directly. In J2SE 5.0, the NVARCHAR2 type is supported indirectly. There is no corresponding java.sql.Types type, but if your application calls the formOfUse(NCHAR) method, then this type can be accessed.

The following table describes Oracle JDBC support for the ANSI-supported SQL data types.

Table A-3 Support for ANSI-92 SQL Data Types

ANSI-Supported SQL Data Type	Supported by JDBC Drivers?
CHARACTER	yes
DEC	yes
DECIMAL	yes
DOUBLE PRECISION	yes

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Table A-3 (Cont.) Support for ANSI-92 SQL Data Types

ANSI-Supported SQL Data Type	Supported by JDBC Drivers?
FLOAT	yes
INT	yes
INTEGER	yes
NATIONAL CHARACTER	no
NATIONAL CHARACTER VARYING	no
NATIONAL CHAR	yes
NATIONAL CHAR VARYING	no
NCHAR	yes
NCHAR VARYING	no
NUMERIC	yes
REAL	yes
SMALLINT	yes
VARCHAR	yes

The following table describes Oracle JDBC driver support for SQL User-Defined types.

Table A-4 Support for SQL User-Defined Types

SQL User-Defined type	Supported by JDBC Drivers?
OPAQUE	yes
Reference types	yes
Object types (`JAVA_OBJECT`)	yes
Nested table types and VARRAY types	yes

The following table describes Oracle JDBC driver support for PL/SQL data types. The PL/SQL data types include the following categories:

- Scalar types
- Scalar character types, which includes `DATE` data type
- Composite types
- Reference types
- Large object (LOB) types

Table A-5 Support for PL/SQL Data Types

PL/SQL Data Type	Supported by JDBC Drivers?
Scalar Types:	
BINARY INTEGER	yes
DEC	yes
DECIMAL	yes
DOUBLE PRECISION	yes

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Table A-5 (Cont.) Support for PL/SQL Data Types

PL/SQL Data Type	Supported by JDBC Drivers?
FLOAT	yes
INT	yes
INTEGER	yes
NATURAL	yes
NATURAL*n*	no
NUMBER	yes
NUMERIC	yes
PLS_INTEGER	yes
POSITIVE	yes
POSITIVE*n*	no
REAL	yes
SIGNTYPE	yes
SMALLINT	yes
BOOLEAN	yes
Scalar Character Types:	
CHAR	yes
CHARACTER	yes
LONG	yes
LONG RAW	yes
NCHAR	no (see Note)
NVARCHAR2	no (see Note)
RAW	yes
ROWID	yes
STRING	yes
UROWID	no
VARCHAR	yes
VARCHAR2	yes
DATE	yes
Composite Types:	
RECORD	no
TABLE	no
VARRAY	yes
Reference Types:	
REF CURSOR types	yes
object reference types	yes
LOB Types:	
BFILE	yes
BLOB	yes
CLOB	yes

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Table A-5 (Cont.) Support for PL/SQL Data Types

PL/SQL Data Type	Supported by JDBC Drivers?
NCLOB	yes

> **Note**
>
> - The types `NATURAL`, `NATURAL`*n*, `POSITIVE`, `POSITIVE`*n*, and `SIGNTYPE` are subtypes of `BINARY INTEGER`.
> - The types `DEC`, `DECIMAL`, `DOUBLE PRECISION`, `FLOAT`, `INT`, `INTEGER`, `NUMERIC`, `REAL`, and `SMALLINT` are subtypes of `NUMBER`.
> - The types `NCHAR` and `NVARCHAR2` are supported indirectly. There is no corresponding `java.sql.Types` type, but if your application calls `formOfUse(NCHAR)`, then these types can be accessed.

Related Topics

- NCHAR, NVARCHAR2, NCLOB and the defaultNChar Property

A.3 About Using PL/SQL Types

Starting from Oracle Database 12*c* Release 1 (12.1), you can map schema-level PL/SQL types as generic `java.sql.Struct` type and PL/SQL collections as `java.sql.Array` types. So, instead of creating schema-level types that are mapped to PL/SQL package types for binding, you can describe and bind PL/SQL types using only the JDBC APIs.

For example, you can call the `Connection.createStruct(type_name)` method to first create a descriptor that can be used to describe a PL/SQL type and then to create a new `STRUCT` representation of this type on the client. In Oracle Database 12*c* Release 1 (12.1), you can reuse this API by specifying `type_name` as `"schema.package.typename"` or `"package.typename"`.

All PL/SQL package types are mapped to a system-wide unique name that can be used by JDBC to retrieve the server-side type metadata. The name is in the following form:

```
[SCHEMA.]<PACKAGE>.<TYPE>
```

> **Note**
>
> If the schema is the same as the package name, and if there is a type with the same name as the PL/SQL type, then it will not be able to identify an object with the two part name format, that is, <package>.<type>. In such cases, you must use three part names <schema>.<package>.<type>.

The following code snippet explains how to bind types declared in PL/SQL packages:

```
/*
---------------------------
# Perform the following SQL operations prior to running this sample
---------------------------
```


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```
conn HR/<password>;
create or replace package TEST_PKG is
   type V_TYP is varray(10) of varchar2(200);
   type R_TYP is record(c1 pls_integer, c2 varchar2(100));
   procedure VARR_PROC(p1 in V_TYP, p2 OUT V_TYP);
   procedure REC_PROC(p1 in R_TYP, p2 OUT R_TYP);
end;
/
create or replace package body TEST_PKG is
 procedure VARR_PROC(p1 in V_TYP, p2 OUT V_TYP) is
  begin
    p2 := p1;
  end;
  procedure REC_PROC(p1 in R_TYP, p2 OUT R_TYP) is
  begin
    p2 := p1;
  end;
end;
/
*/

import java.sql.Array;
import java.sql.CallableStatement;
import java.sql.Connection;
import java.sql.SQLException;
import java.sql.Struct;
import java.sql.Types;

import oracle.jdbc.OracleConnection;
public class PLSQLTypesSample
{
  public static void main(String[] args) throws SQLException
  {
    System.out.println("begin...");
    Connection conn = null;
    oracle.jdbc.pool.OracleDataSource ods = new oracle.jdbc.pool.OracleDataSource();
    ods.setURL("jdbc:oracle:oci:localhost:5521:orcl");
    ods.setUser("HR");
    ods.setPassword("hr");
    //get connection
    conn = ods.getConnection();

    //call procedure TEST_PKG.VARR_PROC
    CallableStatement cstmt = null;
    try {
      cstmt = conn.prepareCall("{ call TEST_PKG.VARR_PROC(?,?) }");
      //PLSQL VARRAY type binding
      Array arr = ((OracleConnection)conn).createArray("TEST_PKG.V_TYP", new String[]
{"A", "B"});
      cstmt.setArray(1, arr);
      cstmt.registerOutParameter(2, Types.ARRAY, "TEST_PKG.V_TYP");
      cstmt.execute();
      //get PLSQL VARRAY type out parameter value
      Array outArr = cstmt.getArray(2);
      //...
    }
    catch( Exception e) {
      e.printStackTrace();
    }finally {
      if (cstmt != null)
        cstmt.close();
    }
```


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```
    //call procedure TEST_PKG.REC_PROC
    try {
      cstmt = conn.prepareCall("{ call TEST_PKG.REC_PROC(?,?) }");
      //PLSQL RECORD type binding
      Struct struct = conn.createStruct("TEST_PKG.R_TYP", new Object[]{12345, "B"});
      cstmt.setObject(1, struct);
      cstmt.registerOutParameter(2, Types.STRUCT, "TEST_PKG.R_TYP");
      cstmt.execute();
      //get PLSQL RECORD type out parameter value
      Struct outStruct = (Struct)cstmt.getObject(2);
      //...
    }
    catch( Exception e) {
      e.printStackTrace();
    }finally {
      if (cstmt != null)
        cstmt.close();
    }

    if (conn != null)
      conn.close();

    System.out.println("done!");
  }
}
```

Creating Java level objects for each row using %ROWTYPE Attribute

You can create Java-level objects using the `%ROWTYPE` attribute. In this case, each row of the table is created as a `java.sql.Struct` object. For example, if you have a package `pack1` with the following specification:

> **See Also**
>
> *Oracle Database PL/SQL Language Reference* for more information about the `%ROWTYPE` attribute

```
CREATE OR REPLACE PACKAGE PACK1 AS
  TYPE EMPLOYEE_ROWTYPE_ARRAY IS TABLE OF EMPLOYEES%ROWTYPE;
END PACK1;
/
```

The following code snippet shows how you can retrieve the value of the `EMPLOYEE_ROWTYPE_ARRAY` array using JDBC APIs:

This example returns a `java.sql.Array` of `java.sql.Struct` objects, where every `Struct` element represents one row of the `EMPLOYEES` table.

Example A-1 Creating Struct Objects for Database Table Rows

```
CallableStatement cstmt = conn.prepareCall("BEGIN SELECT * BULK COLLECT INTO :1 FROM
EMPLOYEE; END;");
cstmt.registerOutParameter(1,OracleTypes.ARRAY, "PACK1.EMPLOYEE_ROWTYPE_ARRAY");
cstmt.execute();
Array a = cstmt.getArray(1);
```


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A.4 Using Embedded JDBC Escape Syntax

Oracle JDBC drivers support some embedded JDBC escape syntax, which is the syntax that you specify between curly braces. The current support is basic.

> **Note**
>
> JDBC escape syntax was previously known as SQL92 Syntax or SQL92 escape syntax.

This section describes the support offered by the drivers for the following constructs:

- Time and Date Literals
- Scalar Functions
- LIKE Escape Characters
- MATCH_RECOGNIZE Clause
- Outer Joins
- Function Call Syntax

Where driver support is limited, these sections also describe possible workarounds.

Disabling Escape Processing

The processing for JDBC escape syntax is enabled by default, which results in the JDBC driver performing escape substitution before sending the SQL code to the database. If you want the driver to use regular Oracle SQL syntax, which is more efficient than JDBC escape syntax processing, then use this statement:

```
stmt.setEscapeProcessing(false);
```

A.4.1 Time and Date Literals

Databases differ in the syntax they use for date, time, and timestamp literals. JDBC supports dates and times written only in a specific format. This section describes the formats you must use for date, time, and timestamp literals in SQL statements.

A.4.1.1 Date Literals

The JDBC drivers support date literals in SQL statements written in the format:

```
{d 'yyyy-mm-dd'}
```

Where `yyyy-mm-dd` represents the year, month, and day. For example:

```
{d '1995-10-22'}
```

The JDBC drivers will replace this escape clause with the equivalent Oracle representation: "22 OCT 1995".

The following code snippet contains an example of using a date literal in a SQL statement.

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```
// Connect to the database
// You can put a database name after the @ sign in the connection URL.
OracleDataSource ods = new OracleDataSource();
ods.setURL("jdbc:oracle:oci:@");
ods.setUser("HR");
ods.setPassword("hr");
Connection conn = ods.getConnection();

// Create a Statement
Statement stmt = conn.createStatement ();

// Select the first name column from the employees table where the hire date is
Jan-23-1982
ResultSet rset = stmt.executeQuery
                 ("SELECT first_name FROM employees WHERE hire_date = {d '1982-01-23'}");

// Iterate through the result and print the employee names
while (rset.next ())
   System.out.println (rset.getString (1));
```

A.4.1.2 Time Literals

The JDBC drivers support time literals in SQL statements written in the format:

```
{t 'hh:mm:ss'}
```

where, `hh:mm:ss` represents the hours, minutes, and seconds. For example:

```
{t '05:10:45'}
```

The JDBC drivers will replace this escape clause with the equivalent Oracle representation: "05:10:45".

If the time is specified as:

```
{t '14:20:50'}
```

Then the equivalent Oracle representation would be "14:20:50", assuming the server is using a 24-hour clock.

This code snippet contains an example of using a time literal in a SQL statement.

```
ResultSet rset = stmt.executeQuery
                 ("SELECT first_name FROM employees WHERE hire_date = {t '12:00:00'}");
```

A.4.1.3 Timestamp Literals

The JDBC drivers support timestamp literals in SQL statements written in the format:

```
{ts 'yyyy-mm-dd hh:mm:ss.f...'}
```

where `yyyy-mm-dd hh:mm:ss.f...` represents the year, month, day, hours, minutes, and seconds. The fractional seconds portion (`.f...`) is optional and can be omitted. For example: `{ts '1997-11-01 13:22:45'}` represents, in Oracle format, NOV 01 1997 13:22:45.

This code snippet contains an example of using a timestamp literal in a SQL statement.

```
ResultSet rset = stmt.executeQuery
    ("SELECT first_name FROM employees WHERE hire_date = {ts '1982-01-23 12:00:00'}");
```


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Mapping SQL DATE Data type to Java

Oracle Database 8*i* and earlier versions did not support `TIMESTAMP` data, but Oracle `DATE` data used to have a time component as an extension to the SQL standard. So, Oracle Database 8*i* and earlier versions of JDBC drivers mapped `oracle.sql.DATE` to `java.sql.Timestamp` to preserve the time component. Starting with Oracle Database 9.0.1, `TIMESTAMP` support was included and 9*i* JDBC drivers started mapping `oracle.sql.DATE` to `java.sql.Date`. This mapping was incorrect as it truncated the time component of Oracle `DATE` data. To overcome this problem, Oracle Database 11*g* Release 1 introduced a new flag `mapDateToTimestamp`. The default value of this flag is `true`, which means that by default the drivers will correctly map `oracle.sql.DATE` to `java.sql.Timestamp`, retaining the time information. If you still want the incorrect but 10*g* compatible `oracle.sql.DATE` to `java.sql.Date` mapping, then you can get it by setting the value of `mapDateToTimestamp` flag to `false`.

Note

- Since Oracle Database 11*g*, if you have an index on a DATE column to be used by a SQL query, then to obtain faster and accurate results, you must use the `setObject` method in the following way:

  ```
  Date d = parseIsoDate(val);
  Timestamp t = new Timestamp(d.getTime());
  stmt.setObject(pos, new oracle.sql.DATE(t, (Calendar)UTC_CAL.clone()));
  ```

  This is because if you use the `setDate` method, then the time component of the Oracle DATE data will be lost and if you use the `setTimestamp` method, then the index on the DATE column will not be used.
- To overcome the problem of `oracle.sql.DATE` to `java.sql.Date` mapping, Oracle Database 9.2 introduced a flag, `V8Compatible`. The default value of this flag was `false`, which allowed the mapping of Oracle `DATE` data to `java.sql.Date` data. But, users could retain the time component of the Oracle `DATE` data by setting the value of this flag to `true`. This flag is desupported since 11*g* because it controlled Oracle Database 8*i* compatibility, which is no longer supported.

A.4.2 Scalar Functions

Oracle JDBC drivers do not support all scalar functions. To find out which functions the drivers support, use the following methods supported by the Oracle-specific `oracle.jdbc.OracleDatabaseMetaData` class and the standard Java `java.sql.DatabaseMetadata` interface:

- `getNumericFunctions()`

  Returns a comma-delimited list of math functions supported by the driver. For example, `ABS`, `COS`, `SQRT`.
- `getStringFunctions()`

  Returns a comma-delimited list of string functions supported by the driver. For example, `ASCII`, `LOCATE`.
- `getSystemFunctions()`

  Returns a comma-delimited list of system functions supported by the driver. For example, `DATABASE`, `USER`.

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- `getTimeDateFunctions()`

  Returns a comma-delimited list of time and date functions supported by the driver. For example, `CURDATE`, `DAYOFYEAR`, `HOUR`.

> **Note**
>
> Oracle JDBC drivers support `fn`, the function keyword.

A.4.3 LIKE Escape Characters

The characters `%` and _ have special meaning in SQL `LIKE` clauses. You use `%` to match zero or more characters and _ to match exactly one character. If you want to interpret these characters literally in strings, then you precede them with a special escape character. For example, if you want to use ampersand (`&`) as the escape character, then you identify it in the SQL statement as:

```
Statement stmt = conn.createStatement ();

// Select the empno column from the emp table where the ename starts with '_'
ResultSet rset = stmt.executeQuery
          ("SELECT empno FROM emp WHERE ename LIKE '&_%' {ESCAPE '&'}");

// Iterate through the result and print the employee numbers
while (rset.next ())
   System.out.println (rset.getString (1));
```

> **Note**
>
> If you want to use the backslash character (\) as an escape character, then you must enter it twice, that is, \\. For example:
>
> ```
> ResultSet rset = stmt.executeQuery("SELECT empno FROM emp
>                 WHERE ename LIKE '_%' {escape '\\'}");
> ```

A.4.4 MATCH_RECOGNIZE Clause

The ? character is used as a token in `MATCH_RECOGNIZE` clause in Oracle Database 11*g* and later versions. As the JDBC standard defines the ? character as a parameter marker, the JDBC Driver and the Server SQL Engine cannot distinguish between different uses of the same token.

In earlier versions of JDBC Driver, if you want to interpret the ? character as a `MATCH_RECOGNIZE` token and not as a parameter marker, then you must use a `Statement` instead of a `PreparedStatement` and disable escape processing. However, starting from Oracle Database 12*c* Release 1 (12.1.0.2), you can use the `'{\\ ... \\}'` syntax while using the ? character, so that the JDBC driver does not process it as a parameter marker and allows the SQL engine to process it. The following code snippet shows how to use the `'{\\ ... \\}'` syntax:

```
String sql =
  "select T.firstW, T.lastZ, ? " +  // use of parameter marker
  "from tkpattern_S11 " +
```


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```
    "MATCH_RECOGNIZE ( " +
    "    MEASURES A.c1 as firstW, last(Z.c1) as lastZ " +
    "    ALL MATCHES " +
    "    {\\ PATTERN(A? X*? Y+? Z??)\\} " +  // use of escape sequence
    "    DEFINE " +
    "        X as X.c2 > prev(X.c2), " +
    "        Y as Y.c2 < prev(Y.c2), " +
    "        Z as Z.c2 > prev(Z.c2)" +
    ") as T";
  PreparedStatement ps = conn.prepareStatatement(sql);
  ps.setString(1, "test");
  ResultSet rs = ps.executeQuery();
```

Related Topics

- Using Embedded JDBC Escape Syntax

A.4.5 Outer Joins

Oracle JDBC drivers do not support the outer join syntax. The workaround is to use Oracle outer join syntax:

Instead of:

```
Statement stmt = conn.createStatement ();
ResultSet rset = stmt.executeQuery
     ("SELECT ename, dname
       FROM {OJ dept LEFT OUTER JOIN emp ON dept.deptno = emp.deptno}
       ORDER BY ename");
```

Use Oracle SQL syntax:

```
Statement stmt = conn.createStatement ();
ResultSet rset = stmt.executeQuery
     ("SELECT ename, dname
       FROM emp b, dept a WHERE a.deptno = b.deptno(+)
       ORDER BY ename");
```

A.4.6 Function Call Syntax

Oracle JDBC drivers support the following procedure and function call syntax:

Procedure calls:

```
{ call procedure_name (argument1, argument2,...) }
```

Function calls:

```
{ ? = call procedure_name (argument1, argument2,...) }
```

A.4.7 JDBC Escape Syntax to Oracle SQL Syntax Example

You can write a simple program to translate JDBC escape syntax to Oracle SQL syntax. The following program prints the comparable Oracle SQL syntax for statements using JDBC escape syntax for function calls, date literals, time literals, and timestamp literals. In the program, the `oracle.jdbc.OracleSql` class `parse()` method performs the conversions.

```
public class Foo
{
   static oracle.jdbc.OracleDriver driver = new oracle.jdbc.OracleDriver();
   public static void main (String args[]) throws Exception
```


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```
   {
      show ("{call foo(?, ?)}");
      show ("{? = call bar (?, ?)}");
      show ("{d '1998-10-22'}");
      show ("{t '16:22:34'}");
      show ("{ts '1998-10-22 16:22:34'}");
   }

   public static void show (String s) throws Exception
   {
      System.out.println (s + " => " +
         driver.processSqlEscapes(s));
   }
}
```

The following code is the output that prints the comparable SQL syntax.

```
{call foo(?, ?)} => BEGIN foo(:1, :2); END;
{? = call bar (?, ?)} => BEGIN :1 := bar (:2, :3); END;
{d '1998-10-22'} => TO_DATE ('1998-10-22', 'YYYY-MM-DD')
{t '16:22:34'} => TO_DATE ('16:22:34', 'HH24:MI:SS')
{ts '1998-10-22 16:22:34'} => TO_TIMESTAMP ('1998-10-22 16:22:34', 'YYYY-MM-DD
HH24:MI:SS.FF')
```

A.5 Oracle JDBC Notes and Limitations

The following limitations exist in the Oracle JDBC implementation, but all of them are either insignificant or have easy workarounds. This section covers the following topics:

- CursorName
- JDBC Outer Join Escapes
- IEEE 754 Floating Point Compliance
- Catalog Arguments to DatabaseMetaData Calls
- SQLWarning Class
- Executing DDL Statements
- Binding Named Parameters

A.5.1 CursorName

Oracle JDBC drivers do not support the `getCursorName` and `setCursorName` methods, because there is no convenient way to map them to Oracle constructs. Oracle recommends using `ROWID` instead.

Related Topics

- Oracle ROWID Type

A.5.2 JDBC Outer Join Escapes

Oracle JDBC drivers do not support JDBC outer join escapes. Use Oracle SQL syntax with + instead.

Related Topics

- Using Embedded JDBC Escape Syntax

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A.5.3 IEEE 754 Floating Point Compliance

The arithmetic for the Oracle `NUMBER` type does not comply with the IEEE 754 standard for floating-point arithmetic. Therefore, there can be small disagreements between the results of computations performed by Oracle and the same computations performed by Java.

Oracle stores numbers in a format compatible with decimal arithmetic and guarantees 38 decimal digits of precision. It represents zero, minus infinity, and plus infinity exactly. For each positive number it represents, it represents a negative number of the same absolute value.

It represents every positive number between 10^{-30} and $(1 – 10^{-38}) * 10^{126}$ to full 38-digit precision.

A.5.4 Catalog Arguments to DatabaseMetaData Calls

Certain `DatabaseMetaData` methods define a `catalog` parameter. This parameter is one of the selection criteria for the method. Oracle does not have multiple catalogs, but it does have packages.

Related Topics

- About Reporting DatabaseMetaData TABLE_REMARKS

A.5.5 SQLWarning Class

The `java.sql.SQLWarning` class provides information about a database access warning. Warnings typically contain a description of the warning and a code that identifies the warning. Warnings are silently chained to the object whose method caused it to be reported. Oracle JDBC drivers generally do not support `SQLWarning`. As an exception to this, scrollable result set operations do generate SQL warnings, but the `SQLWarning` instance is created on the client, not in the database.

Related Topics

- About Processing SQL Exceptions

A.5.6 Executing DDL Statements

You must execute Data Definition Language (DDL) statements with `Statement` objects. If you use `PreparedStatements` objects or `CallableStatements` objects, then the DDL statement takes effect only on the first execution. This can cause unexpected behavior if the SQL statements are in a statement cache.

A.5.7 Binding Named Parameters

Binding by name is not supported when using the `set`*`XXX`* methods. Under certain circumstances, previous versions of Oracle JDBC drivers have allowed binding statement variables by name when using the `set`*`XXX`* methods. In the following statement, the named variable `EmpId` would be bound to the integer `314159`.

```
PreparedStatement p = conn.prepareStatement
  ("SELECT name FROM emp WHERE id = :EmpId");
  p.setInt(1, 314159);
```

This capability to bind by name using the `set`*`XXX`* methods is not part of the JDBC specification, and Oracle does not support it. The JDBC drivers can throw a `SQLException` or produce

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unexpected results. Starting from Oracle Database 10*g* JDBC drivers, bind by name is supported using the `set`*`XXX`*`AtName` methods.

The bound values are not copied by the drivers until you call the `execute` method. So, changing the bound value before calling the `execute` method could change the bound value. For example, consider the following code snippet:

```
PreparedStatement p;
.......
Date d = new Date(1181676033917L);
p.setDate(1, d);
d.setTime(0);
p.executeUpdate();
```

This code snippet inserts `Date(0)` in the database instead of `Date(1181676033917L)` because the bound values are not copied by JDBC driver implementation for performance reasons.

Related Topics

- Interface oracle.jdbc.OracleCallableStatement
- Interface oracle.jdbc.OraclePreparedStatement

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B

Oracle RAC Fast Application Notification

Starting from Oracle Database 12*c* Release 1 (12.1), the Oracle RAC Fast Application Notification (FAN) APIs provide an alternative for taking advantage of the high-availability (HA) features of Oracle Database, if you do not use Universal Connection Pool or Oracle WebLogic Server with Active Grid Link (AGL).

This appendix covers the following topics:

- Overview of Oracle RAC Fast Application Notification
- Installing and Configuring Oracle RAC Fast Application Notification
- Using Oracle RAC Fast Application Notification
- Implementing a Connection Pool

This feature depends on the Oracle Notification System (ONS) message transport mechanism. This feature requires configuring your system, servers, and clients to use ONS.

For using Oracle RAC Fast Application Notification, the `simplefan.jar` file must be present in the `CLASSPATH`, and either the `ons.jar` file must be present in the `CLASSPATH` or an Oracle Notification Services (ONS) client must be installed and running in the client system.

B.1 Overview of Oracle RAC Fast Application Notification

The Oracle RAC Fast Application Notification (FAN) feature provides a simplified API for accessing FAN events through a callback mechanism. This mechanism enables third-party drivers, connection pools, and containers to subscribe, receive and process FAN events. These APIs are referred to as Oracle RAC FAN APIs in this appendix.

The Oracle RAC FAN APIs provide FAN event notification for developing more responsive applications that can take full advantage of Oracle Database HA features. If you do not want to use Universal Connection Pool, but want to work with FAN events implementing your own connection pool, then you should use Oracle RAC Fast Application Notification.

> **Note**
>
> - If you do not want to implement your own connection pool, then you should use Oracle Universal Connection Pool to get all the advantages of Oracle RAC Fast Application Notification, along with many additional benefits.
> - Starting from Oracle Database 12*c* Release 1 (12.1), implicit connection cache (ICC) is desupported. Oracle recommends to use Universal Connection Pool instead.

Your applications are enabled to respond to FAN events in the following way:

- Listening for Oracle RAC service down and node down events.

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- Listening for Oracle RAC service up events representing any Oracle RAC or Global data Service (GDS) start or restart. For these UP events, FAN parameter status is `UP` and `event_type` is one of the following: `database`, `instance`, `service`, or `servicemember`.
- Supporting FAN ONS event syntax and fields for both Oracle Database Release 12*c* and earlier releases, for example, the `event_type` and `timezone` fields added to every event, the `db_domain` field added to every event other than node or public-network events, the `percentf` field added to Run-Time Load Balancing (RLB) events, and so on.
- Listening for load balancing advisory events and responding to them.

This feature exposes the FAN events, which are the notifications sent by a cluster running Oracle RAC, to inform the subscribers about an event happening at the service level or the node level. The supported FAN events are the following:

- Service up

  The service up event notifies the connection pool that a new instance is available for use, allowing sessions to be created on the new instance. The `ServiceUpEvent` Client API is supported in the current release of the Oracle RAC FAN APIs, that is, in the `simplefan.jar` file.

- Service down

  The service down events notify that the managed resources are down and currently not available for access. There are two types of service down events:

  – Events indicating that a particular instance of a service is down and the instance is no longer able to accept work.

  – Events indicating that all-but-one instances of a service are down and the service is no longer able to accept work.

- Node down

  The node down events notify that the Oracle RAC node identified by the host identifier is down and not reachable. The cluster sends node down events when a node is no longer able to accept work.

- Planned down

  Planned down events include all the down events, except node down event. These events have the following two fields set: `status=down` and `reason=user`.

- Load balancing advisory

  The load balancing advisory events provide metrics for load balancing algorithms. Load balancing advisories are sent regularly to inform subscribers of the recommended distribution of work among the available nodes.

> **Note**
>
> If you want to implement your own connection pool, only then you should use Oracle RAC Fast Application Notification. Otherwise, you should use Oracle Universal Connection Pool to get all the advantages of Oracle RAC Fast Application Notification, along with many additional benefits.

Related Topics

- *Oracle Universal Connection Pool Developer's Guide*

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B.2 Installing and Configuring Oracle RAC Fast Application Notification

You can install the Oracle RAC FAN APIs by performing the following steps:

1. Download the `simplefan.jar` file from the following link:

   https://www.oracle.com/database/technologies/appdev/jdbc-downloads.html
2. Add the `simplefan.jar` file to the classpath.
3. Perform the following in your Java code:
   a. Get an instance of the `FanManager` class by using the `getInstance` method.
   b. Configure the event daemon using the `configure` method of the `FanManager` class. The `configure` method sets the following properties:

      `onsNodes`: A comma separated list of `host:port` pairs of ONS daemons that the ONS run time should communicate with. The `host` in a `host:port` pair is the host name of a system running the ONS daemon. The `port` is the local port configuration parameter for that daemon.

      `onsWalletFile`: The path name of the ONS wallet file. The wallet file is the path to a local wallet file used by TLS to store TLS certificates. Same as wallet file configuration parameter to ONS daemon.

      `onsWalletPassword`: The password for accessing the ONS wallet file.

See Also

- For a detailed description of the Oracle RAC FAN APIs, refer to *Oracle Database RAC FAN Events Java API Reference*.
- *Oracle Universal Connection Pool Developer's Guide*

B.3 Using Oracle RAC Fast Application Notification

The following code snippet explains how to handle FAN down events. This example code prints the event data to the standard output device.

This example code demonstrates how to use Oracle RAC FAN APIs by overloading the `handleFanEvent` method to accept different FAN event notifications as arguments. The example code also displays event data such as:

- Name of the system sending the FAN event notification
- Timestamp of the FAN event notification
- Load status of the FAN event notification

Example B-1 Example of Sample Code Using Oracle RAC FAN API for FAN Down Events

```
...
...Properties props = new Properties();
props.putProperty("serviceName", "gl");
FanSubscription sub = FanManager.getInstance().subscribe(props);
```


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```
sub.addListener(new FanEventListener()) {
  public void handleFanEvent(ServiceDownEvent se) {
    try {
      System.out.println(event.getTimestamp());
      System.out.println(event.getServiceName());
      System.out.println(event.getDatabaseUniqueName());
      System.out.println(event.getReason());
      ServiceMemberEvent me = se.getServiceMemberEvent();
      if (me != null) {
        System.out.println(me.getInstanceName());
        System.out.println(me.getNodeName());
        System.out.println(me.getServiceMemberStatus());
      }
      ServiceCompositeEvent ce = se.getServiceCompositeEvent();
      if (ce != null) {
        System.out.println(ce.getServiceCompositeStatus());
      }
    }
    catch (Throwable t) {
      // handle all exceptions and errors
      t.printStackTrace(System.err);
    }
  }
  public void handleFanEvent(NodeDownEvent ne) {
    try {
      System.out.println(event.getTimestamp());
      System.out.println(ne.getNodeName());
      System.out.println(ne.getIncarnation());
    }
    catch (Throwable t) {
      // handle all exceptions and errors
      t.printStackTrace(System.err);
    }
  }
  public void handleFanEvent(LoadAdvisoryEvent le) {
    try {
      System.out.println(event.getTimestamp());
      System.out.println(le.getServiceName());
      System.out.println(le.getDatabaseUniqueName());
      System.out.println(le.getInstanceName());
      System.out.println(le.getPercent());
      System.out.println(le.getServiceQuality());
      System.out.println(le.getLoadStatus());
    }
    catch (Throwable t) {
      // handle all exceptions and errors
      t.printStackTrace(System.err);
    }
  }
});
```

Example B-2 Example of Sample Code Using Oracle RAC FAN API for FAN Up Events

The following code snippet explains how to use Oracle RAC Fast Application Notification for service up events. The code uses the new Oracle RAC FAN APIs introduced in Oracle Database 12*c* Release 2 (12.2.0.1), namely, `FanUpEventListener` interface that extends the `FanEventListener` interface and `ServiceUpEvent`. You must implement the

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`FanUpEventListener` interface in the client application in the similar way you implement the `FanEventListener` interface.

```
import oracle.simplefan.*;

...
FanEventListener fanListener = new FanUpEventListener() {
 public void handleEvent(ServiceUpEvent event) { ..... }

// Specify the next action here, when the node comes up
public void handleEvent(NodeUpEvent event) { ..... }
    ......
}
FanManager fanMngr = FanManager.getInstance();
Properties onsProps = new Properties();
onsProps.setProperty("onsNodes", ......);
fanMngr.configure(onsProps);

Properties subscriptionProps = new Properties();
subscriptionProps.setProperty("serviceName", ......);
fanSubscription = fanMngr.subscribe(subscriptionProps);
fanSubscription.addListener(fanListener);
...
```

B.4 Implementing a Connection Pool

You must implement your own connection pool for using Oracle RAC FAN APIs. Consider the following points before you implement a connection pool using the Oracle RAC FAN APIs:

- Oracle RAC FAN APIs provide a subset of FAN events.
- Oracle RAC FAN APIs support only ONS events. If you want your application to support corresponding supercluster events, then you may require additions to the subscription properties.

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C

JDBC Coding Tips

This appendix describes methods to optimize a Java Database Connectivity (JDBC) application. It includes the following topics:

- JDBC and Multithreading
- Performance Optimization of JDBC Programs
- Transaction Isolation Levels and Access Modes in JDBC

C.1 JDBC and Multithreading

Oracle JDBC drivers provide full support for, and are highly optimized for, applications that use Java multithreading. Controlled serial access to a connection, such as that provided by connection caching, is both necessary and encouraged. However, Oracle strongly discourages sharing a database connection among multiple threads. Avoid allowing multiple threads to access a connection simultaneously. If multiple threads must share a connection, use a disciplined begin-using/end-using protocol.

Keep the following points in mind while working on multithreaded applications:

- Use the `Connection` object as a local variable.
- Close the connection in the `finally` block before exiting the method. For example:

```
Connection conn = null;
try
{
    ...
}
finally
{
   if(conn != null) conn.close();
}
```

- Do not share `Connection` objects between threads.
- Never synchronize on JDBC objects because it is done internally by the driver.
- Use the `Statement.setQueryTimeout` method to set the time to execute a query instead of cancelling the long-running query from a different thread.
- Use the `Statement.cancel` method for SQL operations like `SELECT`, `UPDATE`, or `DELETE`.
- Use the `Connection.cancel` method for SQL operations like `COMMIT`, `ROLLBACK`, and so on.
- Do not use the `Thread.interrupt` method.

C.2 Performance Optimization of JDBC Programs

You can significantly enhance the performance of your JDBC programs by using any of these features:

- Disabling Auto-Commit Mode

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- Standard Fetch Size and Oracle Row Prefetching
- About Setting the Session Data Unit Size
- JDBC Update Batching
- Statement Caching
- Mapping Between Built-in SQL and Java Types

C.2.1 Disabling Auto-Commit Mode

Auto-commit mode indicates to the database whether to issue an automatic `COMMIT` operation after every SQL operation. Being in auto-commit mode can be expensive in terms of time and processing effort if, for example, you are repeating the same statement with different bind variables.

By default, new connection objects are in auto-commit mode. However, you can disable auto-commit mode with the `setAutoCommit` method of the connection object, either `java.sql.Conection` or `oracle.jdbc.OracleConnection`.

In auto-commit mode, the `COMMIT` operation occurs either when the statement completes or the next execute occurs, whichever comes first. In the case of statements returning a `ResultSet` object, the statement completes when the last row of the Result Set has been retrieved or when the Result Set has been closed. In more complex cases, a single statement can return multiple results as well as output parameter values. Here, the `COMMIT` occurs when all results and output parameter values have been retrieved.

If you disable auto-commit mode with a `setAutoCommit(false)` call, then you must manually commit or roll back groups of operations using the `commit` or `rollback` method of the connection object.

Example

The following example illustrates loading the driver and connecting to the database. Because new connections are in auto-commit mode by default, this example shows how to disable auto-commit. In the example, `conn` represents the `Connection` object, and `stmt` represents the `Statement` object.

```
// Connect to the database
// You can put a database host name after the @ sign in the connection URL.
   OracleDataSource ods = new OracleDataSource();
   ods.setURL("jdbc:oracle:oci:@");
   ods.setUser("HR");
   ods.setPassword("hr");
   Connection conn = ods.getConnection();

// It's faster when auto commit is off
conn.setAutoCommit (false);

// Create a Statement
Statement stmt = conn.createStatement ();
...
```


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C.2.2 Standard Fetch Size and Oracle Row Prefetching

Oracle JDBC connection and statement objects allow you to specify the number of rows to prefetch into the client with each trip to the database, while a result set is being populated during a query.

You can set a value in a connection object that affects each statement produced through that connection, and you can override that value in any particular statement object. The default value in a connection object is 10. Prefetching data into the client reduces the number of round-trips to the server.

Similarly, and with more flexibility, JDBC 2.0 enables you to specify the number of rows to fetch with each trip, both for statement objects (affecting subsequent queries) and for result set objects (affecting row refetches). By default, a result set uses the value for the statement object that produced it. If you do not set the JDBC 2.0 fetch size, then the Oracle connection row-prefetch value is used by default.

Related Topics

- Row Fetch Size

C.2.2.1 Row Prefetch Auto Tuning

Starting from Oracle Database Release 23ai, the JDBC Thin driver has a new row prefetch auto-tuning feature.

As mentioned earlier, the default prefetch size is 10. If your application does not alter this default value, then prefetch auto tuning is activated after the fourth fetch because the auto tuning algorithm computes the new prefetch size value based on the average row size in the first three prefetch operations. If your application alters the default prefetch value, then the auto tuning feature is disabled and the prefetch size is set to the value that you specified.

The JDBC connection property `oracle.jdbc.fetchSizeTuning` is also used to control the fetch size tuning behavior. The default value of this property is 8. Setting the value to 0 disables the auto tuning feature. The computed or tuned row prefetch size by the auto tuning algorithm can vary between a minimum value of 4 and a maximum value of 250. The algorithm to compute the row prefetch size is transparent to the user.

> **Note**
>
> The `statement.setFetchSize` method takes priority over the `oracle.jdbc.fetchSizeTuning` method because it disables auto tuning for that particular statement. If you set the fetch size explicitly on a statement, then the auto tuning for that particular statement is disabled. If you set the prefetch size using the `oracle.jdbc.defaultRowPrefetch` connection property, then it affects all statements created from that connection.

> **See Also**
>
> Oracle Database JDBC Java API Reference

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C.2.3 About Setting the Session Data Unit Size

Session data unit (SDU) is a buffer that Oracle Net uses to place data before transmitting it across the network. Oracle Net sends the data in the buffer either when the request is completed or when it is full.

You can configure the SDU and obtain the following benefits, among others:

- Reduction in the time required to transmit a SQL query and result across the network
- Transmission of larger chunks of data

> **Note**
>
> The footprint of the client and the server process increase if you set a bigger SDU size.

> **See Also**
>
> *Oracle Database Net Services Administrator's Guide*

This section describes the following:

- About Setting the SDU Size for the Database Server
- About Setting the SDU Size for JDBC Thin Client

C.2.3.1 About Setting the SDU Size for the Database Server

To set the SDU size for the database server, configure the `DEFAULT_SDU_SIZE` parameter in the `sqlnet.ora` file.

C.2.3.2 About Setting the SDU Size for JDBC OCI Client

The JDBC OCI client uses Oracle Net layer. So, you can set the SDU size for the JDBC OCI client by configuring the `DEFAULT_SDU_SIZE` parameter in the `sqlnet.ora` file.

C.2.3.3 About Setting the SDU Size for JDBC Thin Client

You can set the SDU size for JDBC thin client by specifying it in the `DESCRIPTION` parameter for a particular connection descriptor.

```
sales.example.com=
(DESCRIPTION=
    (SDU=11280)
      (ADDRESS=(PROTOCOL=tcp)(HOST=sales-server)(PORT=5221))
    (CONNECT_DATA=
     (SERVICE_NAME=sales.example.com))
)
```


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C.2.4 JDBC Update Batching

Oracle JDBC drivers enable you to accumulate `INSERT`, `DELETE`, and `UPDATE` operations of prepared statements at the client and send them to the server in batches. This feature reduces round-trips to the server.

> **Note**
>
> Oracle recommends to keep the batch sizes in the range of 100 or less. Larger batches provide little or no performance improvement and may actually reduce performance due to the client resources required to handle the large batch.

C.2.5 Statement Caching

Statement caching improves performance by caching executable statements that are used repeatedly, such as in a loop or in a method that is called repeatedly. Applications use the statement cache to cache statements associated with a particular physical connection. When you enable Statement caching, a Statement object is cached when you call the `close` method. Because each physical connection has its own cache, multiple caches can exist if you enable Statement caching for multiple physical connections.

> **Note**
>
> The Oracle JDBC drivers are optimized for use with the Oracle Statement cache. Oracle strongly recommends that you use the Oracle Statement cache (implicit or explicit).

When you enable Statement caching on a connection cache, the logical connections benefit from the Statement caching that is enabled on the underlying physical connection. If you try to enable Statement caching on a logical connection held by a connection cache, then this will throw an exception.

Related Topics

- Statement and Result Set Caching

C.2.6 Mapping Between Built-in SQL and Java Types

The SQL built-in types are those types with system-defined names, such as `NUMBER`, and `CHAR`, as opposed to the Oracle objects, varray, and nested table types, which have user-defined names. In JDBC programs that access data of built-in SQL types, all type conversions are unambiguous, because the program context determines the Java type to which a SQL datum will be converted.

Table C-1 Mapping of SQL Data Types to Java Classes that Represent SQL Data Types

SQL Data Type	ORACLE Mapping - Java Classes Representing SQL Data Types
`CHAR`	`oracle.sql.CHAR`

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Table C-1 (Cont.) Mapping of SQL Data Types to Java Classes that Represent SQL Data Types

SQL Data Type	ORACLE Mapping - Java Classes Representing SQL Data Types
VARCHAR2	`oracle.sql.CHAR`
DATE	`oracle.sql.DATE`
DECIMAL	`oracle.sql.NUMBER`
DOUBLE PRECISION	`oracle.sql.NUMBER`
FLOAT	`oracle.sql.NUMBER`
INTEGER	`oracle.sql.NUMBER`
REAL	`oracle.sql.NUMBER`
RAW	`oracle.sql.RAW`
LONG RAW	`oracle.sql.RAW`
REF CURSOR	`java.sql.ResultSet`
CLOB LOCATOR	`oracle.jdbc.OracleClob`[1]
BLOB LOCATOR	`oracle.jdbc.OracleBlob`[2]
BFILE	`oracle.sql.BFILE`
nested table	`oracle.jdbc.OracleArray`[3]
varray	`oracle.jdbc.OracleArray`
SQL object value	If there is no entry for the object value in the type map: • `oracle.jdbc.OracleStruct`[4] If there is an entry for the object value in the type map: • customized Java class
REF to SQL object type	class that implements `oracle.sql.SQLRef`, typically by implementing `oracle.jdbc.OracleRef`[5]

1 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.CLOB` class is deprecated and replaced with the `oracle.jdbc.OracleClob` interface.

2 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.BLOB` class is deprecated and replaced with the `oracle.jdbc.OracleBlob` interface.

3 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.ARRAY` class is deprecated and replaced with the `oracle.jdbc.OracleArray` interface.

4 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.STRUCT` class is deprecated and replaced with the `oracle.jdbc.OracleStruct` interface.

5 Starting from Oracle Database 12*c* Release 1 (12.1), the `oracle.sql.REF` class is deprecated and replaced with the `oracle.jdbc.OracleRef` interface.

The most efficient way to access numeric data is to use primitive Java types like `int`, `float`, `long`, and `double`. However, the range of values of these types do not exactly match the range of values of the SQL `NUMBER` data type. As a result, there may be some loss of information. If absolute precision is required across the entire value range, then use the `BigDecimal` type.

All character data is converted to the UCS2 character set of Java. The most efficient way to access character data is as `java.lang.String`. In worst case, this can cause a loss of information when two or more characters in the database character set map to a single UCS2 character. Since Oracle Database 11*g*, all characters in the character set map to the characters in the UCS2 character set. However, some characters do map to surrogate pairs.

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C.3 Transaction Isolation Levels and Access Modes in JDBC

Read-only connections are supported by Oracle JDBC drivers, but not by the Oracle server.

For transactions, the Oracle server supports only the `TRANSACTION_READ_COMMITTED` and `TRANSACTION_SERIALIZABLE` transaction isolation levels. The default is `TRANSACTION_READ_COMMITTED`. Use the following methods of the `oracle.jdbc.OracleConnection` interface to get and set the level:

- `getTransactionIsolation`: Gets the current transaction isolation level of the connection.
- `setTransactionIsolation`: Changes the transaction isolation level, using either the `TRANSACTION_READ_COMMITTED` or the `TRANSACTION_SERIALIZABLE` value.

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D

JDBC Error Messages

All the JDBC error messages are now listed in the Database Error Portal.

See Also

Database Error Messages

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E
Troubleshooting

This appendix describes how to troubleshoot a Java Database Connectivity (JDBC) application in the following topics:

- Common Problems
- Basic Debugging Procedures

E.1 Common Problems

This section describes some common problems that you might encounter while using Oracle JDBC drivers. These problems include:

- Memory Consumption for CHAR Columns Defined as OUT or IN/OUT Variables
- Memory Leaks and Running Out of Cursors
- Opening More than 16 OCI Connections for a Process
- Using statement.cancel
- Using JDBC with Firewalls
- Frequent Abrupt Disconnection from Server
- Network Adapter Cannot Establish Connection

E.1.1 Memory Consumption for CHAR Columns Defined as OUT or IN/OUT Variables

In PL/SQL, when a `CHAR` or a `VARCHAR2` column is defined as a `OUT` or `IN/OUT` variable, the driver allocates a `CHAR` array of 32512 chars. This can cause a memory consumption problem. JDBC Thin driver does not allocate memory when using `VARCHAR2` output type. But JDBC OCI driver allocates memory for both `CHAR` and `VARCHAR2` types. So, CPU load in OCI driver is higher than Thin driver.

At previous releases, the solution to the problem was to invoke the `Statement.setMaxFieldSize` method. A better solution is to use `OracleCallableStatement.registerOutParameter`. Oracle encourages you always to call `registerOutParameter (int paramIndex, int sqlType, int scale, int maxLength)` on each `CHAR` or `VARCHAR2` column. This method is defined in `oracle.jdbc.OracleCallableStatement`. Use the fourth argument, `maxLength`, to limit the memory consumption. This parameter tells the driver how many characters are necessary to store this column. The column is truncated if the character array cannot hold the column data. The third argument, `scale`, is ignored by the driver.

E.1.2 Memory Leaks and Running Out of Cursors

If you receive messages that you are running out of cursors or that you are running out of memory, make sure that all your `Statement` and `ResultSet` objects are explicitly closed. Oracle JDBC drivers do not have finalizer methods. They perform cleanup routines by using the `close`

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method of the `ResultSet` and `Statement` classes. If you do not explicitly close your result set and statement objects, significant memory leaks can occur. You could also run out of cursors in the database. Closing a statement releases the corresponding cursor in the database.

Similarly, you must explicitly close `Connection` objects to avoid leaking and running out of cursors on the server-side. When you close the connection, the JDBC driver closes any open statement objects associated with it, thus releasing the cursor on the server-side.

E.1.3 Opening More than 16 OCI Connections for a Process

You may find that you are unable to open more than approximately 16 JDBC-OCI connections for a process at any given time. The most likely reasons for this would be either that the number of processes on the server exceeded the limit specified in the initialization file, or that the per-process file descriptors limit was exceeded. It is important to note that one JDBC-OCI connection can use more than one file descriptor (it might use anywhere between 3 and 4 file descriptors).

If the server allows more than 16 processes, then the problem could be with the per-process file descriptor limit. The possible solution would be to increase this limit.

E.1.4 Using statement.cancel

The JDBC standard method `Statement.cancel` attempts to cleanly stop the execution of a SQL statement by sending a message to the database. In response, the database stops execution and replies with an error message. The Java thread that invoked `Statement.execute` waits on the server, and continues execution only when it receives the error reply message invoked by the call of the other thread to `Statement.cancel` method.

As a result, the `Statement.cancel` method relies on the correct functioning of the network and the database. If either the network connection is broken or the database server is hung, the client does not receive the error reply to the cancel message. Frequently, when the server process dies, JDBC receives an `IOException` that frees the thread that invoked `Statement.execute`. In some circumstances, the server is hung, but JDBC does not receive an `IOException`. The `Statement.cancel` method does not free the thread that initiated the `Statement.execute` method.

> **Note**
>
> Remember the following points while working with the `Statement.cancel` method:
>
> - Distinguish between Connection-level and Statement-level cancel. If a nonstatement execution, for example, a `ROLLBACK` is cancelled by a `statement.cancel` method, then we replay the command (only if it is `ROLLBACK`, `COMMIT`, `autoCommit ON`, `autoCommit OFF`, `VERSION`). To guarantee data integrity, we do not replay statement executions.
> - Synchronize statement execution and statement cancel, so that the execution does not return until the cancel call is sent to the Database. This provides a better chance for the executing statement to be cancelled.
> - Synchronize cancel calls, so that any new cancel request is ignored until the cancel in progress has completed the full protocol, that is, after the database receives an interrupt, act on it, and notify JDBC.

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When JDBC does not receive an `IOException`, Oracle Net may eventually time out and close the connection. This causes an `IOException` and frees the thread. This process can take many minutes. For information about how to control this time-out, see the description of the `readTimeout` property for `OracleDatasource.setConnectionProperties`. You can also tune this time-out with certain Oracle Net settings.

The JDBC standard method `Statement.setQueryTimeout` relies on the `Statement.cancel` method. If execution continues longer than the specified time-out interval, then the monitor thread calls the `Statement.cancel` method. This is subject to all the same limitations described previously. As a result, there are cases when the time-out does not free the thread that invoked the `Statement.execute` method.

The length of time between execution and cancellation is not precise. This interval is no less than the specified time-out interval but can be several seconds longer. If the application has active threads running at high priority, then the interval can be arbitrarily longer. The monitor thread runs at high priority, but other high priority threads may keep it from running indefinitely. Note that the monitor thread is started only if there are statements executed with non zero time-out. There is only one monitor thread that monitors all Oracle JDBC statement execution.

> **Note**
>
> The `Statement.cancel` method and the `Statement.setQueryTimeout` method are not supported in the server-side internal driver. The server-side internal driver runs in the single-threaded server process and the Oracle JVM implements Java threads within this single-threaded process. If the server-side internal driver is executing a SQL statement, then no Java thread can call the `Statement.cancel` method. This also applies to the Oracle JDBC monitor thread.

E.1.5 Using JDBC with Firewalls

Firewall timeout for idle-connections may sever a connection. This can cause JDBC applications to hang while waiting for a connection. You can perform one or more of the following actions to avoid connections from being severed due to firewall timeout:

- If you are using connection caching or connection pooling, then always set the inactivity timeout value on the connection cache to be shorter than the firewall idle timeout value.
- Pass `oracle.jdbc.ReadTimeout` as connection property to enable read timeout on socket. The timeout value is in milliseconds.
- For both JDBC OCI and JDBC Thin drivers, use net descriptor to connect to the database and specify the `ENABLE=BROKEN` parameter in the `DESCRIPTION` clause in the connect descriptor. Also, set a lower value for `TCP_KEEPALIVE_INTERVAL`.
- Enable Oracle Net DCD by setting `SQLNET.EXPIRE_TIME=1` in the `sqlnet.ora` file on the server-side.

E.1.6 Frequent Abrupt Disconnection from Server

If the network is not reliable, then it is difficult for a client to detect the frequent disconnections when the server is abruptly disconnected. By default, a client running on Linux takes 7200 seconds (2 hours) to sense the abrupt disconnections. This value is equal to the value of the `tcp_keepalive_time` property. If you want your application to detect the disconnections faster, then you must set the value of the `tcp_keepalive_time`, `tcp_keepalive_interval`, and `tcp_keepalive_probes` properties to a lower value at the operating system level.

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> **Note**
>
> Setting a low value for the `tcp_keepalive_interval` property leads to frequent probe packets on the network, which can make the system slower. So, the value of this property should be set appropriately based on the system requirements.

Also, you must specify the `ENABLE=BROKEN` parameter in the `DESCRIPTION` clause in the connection descriptor. For example:

```
jdbc:oracle:thin:@(DESCRIPTION=(ENABLE=BROKEN)(ADDRESS=(PROTOCOL=tcp)(PORT=5221)
(HOST=myhost))(CONNECT_DATA=(SERVICE_NAME=orcl)))
```

E.1.7 Network Adapter Cannot Establish Connection

You may receive the following error while trying to establish a connection from a JDBC application to an Oracle instance:

```
java.sql.SQLException: Io exception:
  The Network Adapter could not establish connection

SQLException: SQLState (null) vendor code (17002)
```

This error may occur even if all or any of the following conditions is true:

- You are able to establish a SQL*Plus connection from the same client to the same Oracle instance.
- You are able to establish a JDBC OCI connection, but not a JDBC Thin connection from the same client to the same Oracle instance.
- The same JDBC application is able to connect from a different client to the same Oracle instance.
- The same behavior applies whether the initial JDBC connection string specifies a host name or an IP address.

One or more of the following reasons can cause this error:

- The host name to which you are trying to establish the connection is incorrect.
- The port number you are using to establish the connection is wrong.
- The NIC card supports both IPv4 and IPv6.
- The Oracle instance is configured for MTS, but the JDBC connection uses a shared server instead of a dedicated server.

You can quickly diagnose these above-mentioned reasons by using SQL*Plus, except for the issue with the NIC card. The following sections specify how to resolve this error, and also contains a sample application:

- Oracle Instance Configured with MTS Server Uses Shared Server
- JDBC Thin Driver with NIC Card Supporting Both IPv4 and IPv6
- Sample Application

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E.1.7.1 Oracle Instance Configured with MTS Server Uses Shared Server

For resolving this error, you must verify whether the Oracle instance is configured for Multi-threaded Server (MTS) or not. If the Oracle instance is not configured for MTS, then it must be configured.

If the Oracle instance is configured for MTS, then you must force the JDBC connection to use a dedicated server instead of a shared server. You can achieve this by reconfiguring the server to use dedicated connections only. If it is not feasible to configure your server to use only dedicated connections, then you perform the following steps to set it from the client side:

For JDBC OCI Client

1. Add the `(SERVER=DEDICATED)` property to the TNS connection string stored in the `tnsnames.ora` file on the client.
2. Set the `USER_DEDICATED_SERVER=ON` in the `sqlnet.ora` file on the client.

For JDBC Thin:

You must specify a full name-value pair connection string (the same as it may appear in the `tnsnames.ora` file) instead of the short JDBC Thin syntax. For example, instead of the "`jdbc:oracle:thin:@host:port:sid`" connection string, you must use a connection string of the following form:

```
"jdbc:oracle:thin:@(DESCRIPTION="                  +
                    "(ADDRESS_LIST="               +
                        "(ADDRESS=(PROTOCOL=TCP)" +
                                "(HOST=host)"      +
                                "(PORT=port)"      +
                        ")"                        +
                    ")"                            +
                    "(CONNECT_DATA="               +
                        "(SERVICE_NAME=sid)"       +
                        "(SERVER=DEDICATED)"       +
                    ")"                            +
                  ")"
```

E.1.7.2 JDBC Thin Driver with NIC Card Supporting Both IPv4 and IPv6

If the Network Interface Controller (NIC) card of the server is configured to support both IPv4 and IPv6, then some services may start with IPv6. Any client application that tries to connect using IPv4 to the service that is running with IPv6 (or the other way round) receives a connection refused error. If a JDBC thin client application tries to connect to the Database server, then the application may stop responding or fail with the following error:

```
java.sql.SQLException: Io exception: The Network Adapter could not establish the
connection Error Code: 17002
```

Use any of the following solutions to resolve this error:

- Indicate the Java Virtual Machine (JVM) to use IP protocol version 4. Launch the JVM, where the JDBC application is running, with the `-Djava.net.preferIPv4Stack` parameter as `true`. For example, suppose you are running a JDBC application named `jdbcTest`. Then execute the application in the following way:

  ```
  java -Djava.net.preferIPv4Stack=true jdbcTest
  ```

- Use the OCI JDBC driver.

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E.1.7.3 Sample Application

Example E-1 shows a basic JDBC program that connects to a Database and can be used to test your connection. It enables to try all forms of connection using Oracle JDBC drivers.

Example E-1 Basic JDBC Program to Connect to a Database in Five Different Ways

```
import java.sql.*;
public class Jdbctest
{
   public static void main (String args[])
   {
         try
         {
                  /* Uncomment the next line for more connection information */
                  // DriverManager.setLogStream(System.out);
                  /* Set the host, port, and sid below to match the entries in the
listener.ora */
                  String host = "myhost.oracle.com";
                  String port = "5221";
                  String sid  = "orcl";
                  // or pass on command line arguments for all three items
                  if ( args.length >= 3 )
                  {
                            host = args[0];
                            port = args[1];
                            sid  = args[2];
                  }

                  String s1 = "jdbc:oracle:thin:@" + host + ":" + port + ":" + sid ;
                  if ( args.length == 1 )
                  {
                            s1 =  "jdbc:oracle:oci8:@" + args[0];
                  }
                  if ( args.length == 4 )
                  {
                             s1 = "jdbc:oracle:" + args[3] + ":@" +
                                  "(description=(address=(host=" + host+ ")
(protocol=tcp)(port=" + port+ "))(connect_data=(sid="+ sid + ")))";
                  }
                  System.out.println( "Connecting with: " );
                  System.out.println( s1 );
                  DriverManager.registerDriver(new oracle.jdbc.driver.OracleDriver());
                  Connection conn =
DriverManager.getConnection( s1,"hr","hr");
                  DatabaseMetaData dmd = conn.getMetaData();
                  System.out.println("DriverVersion:["+dmd.getDriverVersion()+"]");
                  System.out.println("DriverMajorVersion: ["+dmd.getDriverMajorVersion()
+"]");
                  System.out.println("DriverMinorVersion: ["+dmd.getDriverMinorVersion()
+"]");
                  System.out.println("DriverName:["+dmd.getDriverName()+"]");
                  if ( conn!=null )
                     conn.close();
                  System.out.println("Done.");
           }
           catch ( SQLException e )
           {
                  System.out.println ("\n*** Java Stack Trace ***\n");
                  e.printStackTrace();
                  System.out.println ("\n*** SQLException caught ***\n");
```


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```
                    while ( e != null )
                    {
                              System.out.println ("SQLState: " + e.getSQLState
());
                              System.out.println ("Message:  " + e.getMessage
());
                              System.out.println ("Error Code:   " + e.getErrorCode
());
                              e = e.getNextException ();
                              System.out.println ("");
                     }
               }
  }
}
```

E.2 Basic Debugging Procedures

This section describes strategies for debugging a JDBC program:

- Oracle Net Tracing to Trap Network Events
- Third Party Debugging Tools

Related Topics

- About Processing SQL Exceptions

E.2.1 Oracle Net Tracing to Trap Network Events

You can enable client and server Oracle-Net trace to trap the packets sent over Oracle Net. You can use client-side tracing only for the JDBC OCI driver; it is not supported for the JDBC Thin driver.

The trace facility produces a detailed sequence of statements that describe network events as they execute. "Tracing" an operation lets you obtain more information about the internal operations of the event. This information is printed to a readable file that identifies the events that led to the error. Several Oracle Net parameters in the `SQLNET.ORA` file control the gathering of trace information. After setting the parameters in `SQLNET.ORA`, you must make a new connection for tracing to be performed.

The higher the trace level, the more detail is captured in the trace file. Because the trace file can be hard to understand, start with a trace level of 4 when enabling tracing. The first part of the trace file contains connection handshake information, so look beyond this for the SQL statements and error messages related to your JDBC program.

> **Note**
>
> The trace facility uses a large amount of disk space and might have significant impact upon system performance. Therefore, enable tracing only when necessary.

Related Topics

- *Oracle Call Interface Programmer's Guide*

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E.2.1.1 Client-Side Tracing

Set the following parameters in the `SQLNET.ORA` file on the client system.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), Oracle recommends you to use the configuration parameters present in the new XML configuration file `oraaccess.xml` instead of the OCI-specific configuration parameters present in the `sqlnet.ora` file. However, the configuration parameters present in the `sqlnet.ora` file are still supported.

E.2.1.1.1 TRACE_LEVEL_CLIENT

Purpose:

Turns tracing `on` or `off` to a certain specified level.

Default Value:

0 or OFF

Available Values:

- 0 or `OFF` - No trace output
- 4 or `USER` - User trace information
- 10 or `ADMIN` - Administration trace information
- 16 or `SUPPORT` - WorldWide Customer Support trace information

Example:

```
TRACE_LEVEL_CLIENT=10
```

E.2.1.1.2 TRACE_DIRECTORY_CLIENT

Purpose:

Specifies the destination directory of the trace file.

Default Value:

ORACLE_HOME`/network/trace`

Example:

UNIX: `TRACE_DIRECTORY_CLIENT=/oracle/traces`

Windows: `TRACE_DIRECTORY_CLIENT=C:\ORACLE\TRACES`

E.2.1.1.3 TRACE_FILE_CLIENT

Purpose:

Specifies the name of the client trace file.

Default Value:

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SQLNET.TRC

Example:

```
TRACE_FILE_CLIENT=cli_Connection1.trc
```

> **Note**
>
> Ensure that the name you choose for the TRACE_FILE_CLIENT file is different from the name you choose for the TRACE_FILE_SERVER file.

E.2.1.1.4 TRACE_UNIQUE_CLIENT

Purpose:

Gives each client-side trace a unique name to prevent each trace file from being overwritten with the next occurrence of a client trace. The PID is attached to the end of the file name.

Default Value:

OFF

Example:

```
TRACE_UNIQUE_CLIENT = ON
```

E.2.1.2 Server-Side Tracing

Set the following parameters in the SQLNET.ORA file on the server system. Each connection will generate a separate file with a unique file name.

> **Note**
>
> Starting from Oracle Database 12*c* Release 1 (12.1), Oracle recommends you to use the configuration parameters present in the new XML configuration file oraaccess.xml instead of the OCI-specific configuration parameters present in the sqlnet.ora file. However, the configuration parameters present in the sqlnet.ora file are still supported.

E.2.1.2.1 TRACE_LEVEL_SERVER

Purpose:

Turns tracing on or off to a certain specified level.

Default Value:

0 or OFF

Available Values:

- 0 or OFF - No trace output
- 4 or USER - User trace information
- 10 or ADMIN - Administration trace information

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- 16 or SUPPORT - WorldWide Customer Support trace information

Example:

```
TRACE_LEVEL_SERVER=10
```

E.2.1.2.2 TRACE_DIRECTORY_SERVER

Purpose:

Specifies the destination directory of the trace file.

Default Value:

ORACLE_HOME/network/trace

Example:

```
TRACE_DIRECTORY_SERVER=/oracle/traces
```

E.2.1.2.3 TRACE_FILE_SERVER

Purpose:

Specifies the name of the server trace file.

Default Value:

SERVER.TRC

Example:

```
TRACE_FILE_SERVER= svr_Connection1.trc
```

> **Note**
>
> Ensure that the name you choose for the TRACE_FILE_SERVER file is different from the name you choose for the TRACE_FILE_CLIENT file.

E.2.2 Third Party Debugging Tools

You can use tools such as JDBCSpy and JDBCTest from Intersolv to troubleshoot at the JDBC API level. These tools are similar to ODBC Spy and ODBC Test tools.

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