Oracle® TimesTen In-Memory Database

Introduction

Release 22.1
F35387-05
April 2025

Oracle TimesTen In-Memory Database Introduction, Release 22.1

F35387-05

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About This Content

This guide provides basic conceptual information about TimesTen and its features.

Audience

This guide is intended for anyone interested in knowing conceptual information about the Oracle TimesTen In-Memory Database (TimesTen). TimesTen is a relational database that is memory-optimized for fast response and high throughput. The database resides entirely in memory at runtime and is persisted to the file system.

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Conventions

The following text conventions are used in this document.

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

What's New

This section summarizes new features and functionality of TimesTen Release 22.1 that are documented in this guide, providing links into the guide for more information.

New Features in Release 22.1.1.1.0

- TimesTen Scaleout now supports static read-only cache groups with incremental autorefresh. See Cache Groups.
- If an application process wants to use both direct and client/server TimesTen drivers, then it should link with an ODBC driver manager. In this release, a TimesTen-specific driver manager is provided. The TimesTen driver manager is a transparent, low overhead option designed specifically for this use case and supports all TimesTen functionality. See Driver Manager Connection.

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Overview for the Oracle TimesTen In-Memory Database

Oracle TimesTen In-Memory Database (TimesTen) is a memory-optimized relational database that empowers applications with the responsiveness and high throughput required by today's real-time enterprises and industries such as telecom, capital markets, and defense. TimesTen supports SQL, standard APIs, complete ACID properties, and highly available replication mechanisms. The database resides entirely in physical memory and is persistent and recoverable.

- Oracle TimesTen In-Memory Database in classic mode (TimesTen Classic) is a memory-optimized relational database that provides applications with the responsiveness and high throughput. High availability for the in-memory database is provided through transactional replication.
- Oracle TimesTen In-Memory Database in grid mode (TimesTen Scaleout) is a grid of interconnected hosts running TimesTen Scaleout instances that work together to provide fast access, fault tolerance, and high availability for in-memory data. K-safety provides fault tolerance by enabling you to define the number of copies of data to ensure that your database continues to operate in spite of various faults (as long as a single copy of the data is accessible). A grid contains one or more databases and each database is distributed across all instances of the grid.
- Cache is ideal for caching performance-critical subsets of an Oracle database for improved response time in the application tier. Cache tables can be read-only or updatable. Applications read and update the cache tables using standard SQL, and data synchronization between the cache and the Oracle database is performed automatically. Cache offers applications the full generality and functionality of a relational database, the transparent maintenance of cache consistency with the Oracle database, and the high performance of an in-memory database.

The following sections provide an overview for TimesTen:

TimesTen Database Performance Overview

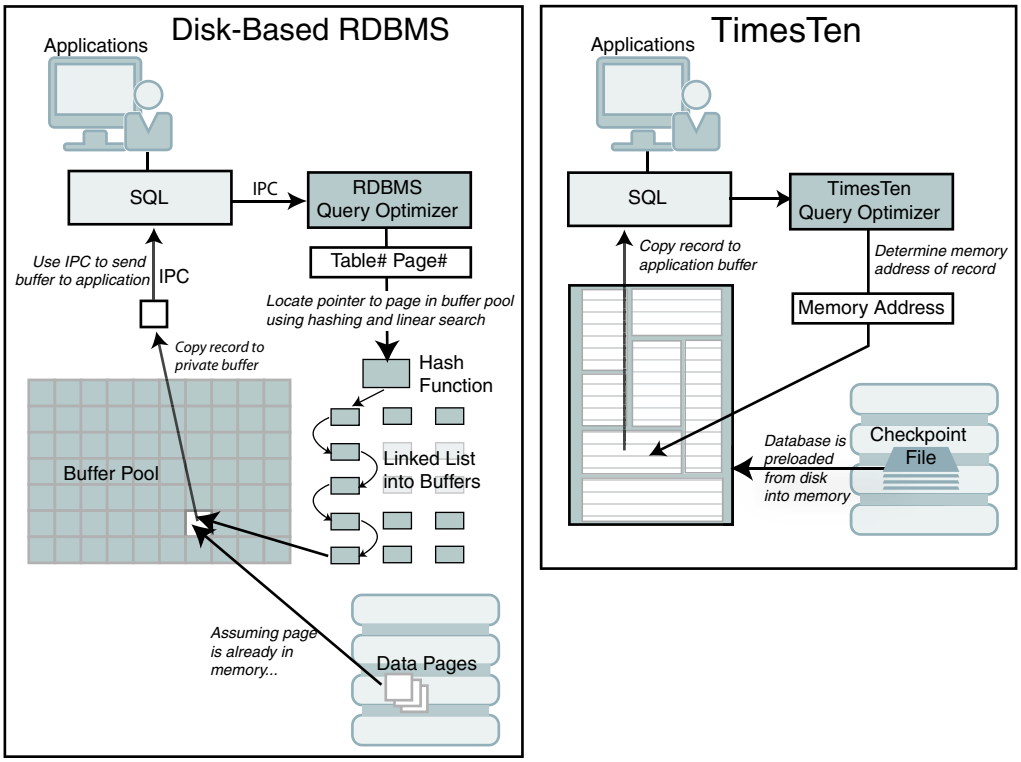
Much of the work that is done by a conventional RDBMS is done under the assumption that data primarily resides on the file system. Optimization algorithms, buffer pool management, and indexed retrieval techniques are designed based on this fundamental assumption.

Even when a file system-based RDBMS has been configured to hold all of its data in main memory, its performance is limited by assumptions of the data residency. These assumptions cannot be easily reversed because they are hard-coded in processing logic, indexing schemes, and data access mechanisms.

Because the TimesTen database resides in physical memory, access to data is more direct, resulting in a shorter code path, simpler algorithms, and internal data structures. Thus, TimesTen delivers performance by optimizing data residency at run time. By managing data in physical memory and optimizing data structures and access algorithms accordingly, database operations run with maximum efficiency, achieving dramatic gains in responsiveness and throughput.

When the assumption of the file system is removed, complexity is dramatically reduced. The number of machine instructions drops, buffer pool management disappears, extra data copies are not needed, index pages shrink, and their structure is simplified. The design becomes simple and more compact, and requests are processed faster. Figure 1-1 shows the simplicity of the TimesTen design.

Figure 1-1 Comparing a File System-Based RDBMS to TimesTen Classic



Both TimesTen Scaleout and TimesTen Classic deliver high performance since they all use the Oracle TimesTen In-Memory Database as their RDBMS. TimesTen Scaleout provides the best throughput; TimesTen Classic provides the best latency. The TimesTen in-memory database delivers high performance by changing the assumptions about where data resides at runtime. The TimesTen in-memory database manages data in memory and optimizes data structures and access algorithms accordingly. Thus, database operations run with maximum efficiency, achieving dramatic gains in responsiveness and throughput, even compared with a fully cached, the file system-based relational database management system (RDBMS).

TimesTen In-Memory Database General Feature Overview

Unless otherwise indicated, TimesTen Scaleout and TimesTen Classic have the same database features.

TimesTen API and Language Support

TimesTen supports:

- Industry standard language for RDBMS: SQL.
- Industry standard APIs: ODBC, JDBC, and ODP.NET.
- Oracle APIs: PL/SQL, Oracle Call Interface (OCI), and ProC/C++.
- TTClasses and built-in procedures provided by TimesTen that extend ODBC functionality for TimesTen-specific operations.
- Open source programming languages, such as Python and Node.js.

The runtime architecture of TimesTen supports connectivity through the ODBC, JDBC, OCI, Pro*C/C++ Precompiler and ODP.NET APIs.

SQL and PL/SQL Functionality

TimesTen supports extensive SQL functionality to simplify the configuration and management of special features. Using SQL to shield applications from system internals enables a database to be altered or extended without impacting existing applications. New services can be quickly added into a production environment simply by adding application modules, tables, and columns. Any developer familiar with the Oracle database or SQL interfaces can be immediately productive developing applications with TimesTen. See SQL Statements in the *Oracle TimesTen In-Memory Database SQL Reference*.

TimesTen supports Oracle PL/SQL (Procedural Language Extension to SQL), a programming language that enables you to integrate procedural constructs with SQL for a TimesTen in-memory database. You can run PL/SQL from all supported APIs. See Introduction to PL/SQL in TimesTen in the *Oracle TimesTen In-Memory Database PL/SQL Developer's Guide*.

OCI, ODBC and JDBC Interfaces

TimesTen supports the Oracle Call Interface (OCI) for TimesTen functionality.

TimesTen OCI support enables you to run many existing OCI applications with TimesTen in direct mode or client/server mode. TimesTen OCI also enables you to use other Oracle Database products that use OCI as a database interface. You can call PL/SQL from OCI applications.

TimesTen also supports the industry standard ODBC and JDBC API interfaces. TimesTen supports versions of these APIs that are both fully compliant with the standards and tuned for maximum performance in the TimesTen environment.

Unlike many other database systems, where the ODBC API support may be much slower than the proprietary interface, ODBC is a native TimesTen interface that operates directly with the database engine.

See TimesTen Support for OCI and Working with TimesTen Databases in ODBC in the *Oracle TimesTen In-Memory Database C Developer's Guide* and Working with TimesTen Databases in JDBC in the *Oracle TimesTen In-Memory Database Java Developer's Guide*.

Pro*C/C++ Precompiler Support

TimesTen supports the Oracle Pro*C/C++ Precompiler for C and C++ applications. You can use the precompiler with embedded SQL and PL/SQL applications that access a TimesTen database. Further, you can use your C or C++ program host variables in your embedded SQL or PL/SQL. See TimesTen Support for Pro*C/C++ in the *Oracle TimesTen In-Memory Database C Developer's Guide*.

ODP.NET Support

Oracle Data Provider for .NET (ODP.NET) is an implementation of the Microsoft ADO.NET interface. ODP.NET support for TimesTen provides fast and efficient ADO.NET data access from .NET and C# client applications to a TimesTen in-memory database.

See Initial Considerations for ODP.NET in a TimesTen Environment in the *Oracle Data Provider for .NET Oracle TimesTen In-Memory Database Support User's Guide*.

Open Source Programming Languages

TimesTen supports open source programming languages, Python and Node.js, to access any TimesTen database through the Oracle Database ODPI-C driver.

ODPI-C is an open source library from Oracle Corporation designed to simplify access to Oracle databases from a variety of programming languages. It is a layer on top of the Oracle Call Interface.

See Getting Started in the *Oracle TimesTen In-Memory Database Open Source Languages Support Guide* for more details.

TTClasses

TimesTen C++ Interface Classes (TTClasses) is more convenient than ODBC while maintaining fast performance. This C++ class library provides wrappers around the most common ODBC functionality. The TTClasses library is also intended to promote best practices when writing application software.

See TTClasses Development Environment in the *Oracle TimesTen In-Memory Database TTClasses Guide*.

Transactional ACID Compliance

TimesTen supports transactions that provide atomic, consistent, isolated and durable (ACID) access to data. All operations on a TimesTen database, even those that do not modify or access application data, run within a transaction. See Transaction Isolation, Durability in this guide and Transaction Management in the *Oracle TimesTen In-Memory Database Operations Guide*.

Durability

A database in TimesTen is persistent across power failures and crashes. TimesTen accomplishes durability by periodically writing to the file system:

- Changes made by transactions through transaction log files.

  Transaction log records are written to the file system asynchronously or synchronously to the completion of the transaction and controlled by the application at the transaction level. For systems where maximum throughput is paramount, such as non-monetary transactions within network systems, asynchronous logging enables extremely high throughput with minimal exposure. In cases where data integrity must be preserved, such as securities trading, TimesTen ensures complete durability, with no loss of data. See Transaction Logging and When Are Transaction Log Files Deleted?.

- All data through checkpoint files.

  TimesTen maintains the file system version of the database with a checkpoint operation that takes place in the background and has very little impact on database applications. This operation is performed automatically. TimesTen maintains two checkpoint files in case a failure occurs mid-checkpoint. Checkpoint files should reside on a file system separate from the transaction logs files to minimize the impact of checkpointing on application activity. See Checkpointing.

Durability for TimesTen Classic

TimesTen Classic uses the transaction log in the following situations:

- Recover transactions if the application or database fails
- Undo transactions that are rolled back
- Replicate changes to other TimesTen databases
- Replicate TimesTen changes to Oracle Database tables
- Enable applications to detect changes to tables (using the XLA API)

See Durable Options for Logging Transactions in the *Oracle TimesTen In-Memory Database Operations Guide*.

Durability for TimesTen Scaleout

In TimesTen Scaleout, the data in your database is distributed into elements. Each element keeps its own checkpoint and transaction log files. As a result, the data stored in each element is independently durable.

Each instance in a grid manages one element of a database. In the event of a failure, an instance can automatically recover the data stored in its element from the checkpoint and transaction logs files while the remaining instances continue to service applications.

TimesTen Scaleout also enables you to keep multiple copies of your data to increase durability and fault tolerance.

You can change the durability settings of a database according to your performance and data durability needs. For example, you may choose if data is flushed to the file system with every commit or periodically in batches in order to operate at a higher performance level.

See Durability Settings in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Performance Through Query Optimization

As with any mainstream RDBMS, a cost-based optimizer automatically determines the fastest way to process queries and transactions. TimesTen has a cost-based query optimizer that chooses the best query execution plan based on factors such as the presence of indexes, the cardinality of tables, and the presence of `ORDER BY` clauses in the query.

The method that the TimesTen optimizer analyzes SQL statements to minimize performance costs is different than in traditional file system-based systems, because the cost structure of a main-memory system differs from that of file systems in which access is a dominant cost factor. Because access to the file system is not a factor in TimesTen, the optimization cost model includes factors not usually considered by optimizers for file systems, such as the cost of evaluating predicates.

TimesTen provides range and hash indexes. The query optimizer also uses two types of join methods (nested-loop and merge-join). The optimizer can create temporary indexes as needed. The optimizer accepts hints that provide applications the decision on whether to make tradeoffs between factors, such as temporary space usage and performance.

See Query Optimization for more information about the query optimizer and indexing techniques.

Concurrency

TimesTen provides full support for shared databases. Options are available so users can choose the optimum balance between response time, throughput and transaction semantics for an application.

Read-committed isolation provides nonblocking operations and is the default isolation level. For databases with extremely strict transaction semantics, serializable isolation is available. These isolation levels conform to the ODBC standard and are implemented with optimal performance in mind. As defined by the ODBC standard, a default isolation level can be set for a TimesTen database, which can be dynamically modified for each connection at runtime.

See Concurrent Operations for more information about managing concurrent operations in TimesTen.

Database Character Sets and Globalization Support

TimesTen provides globalization support for storing, retrieving, and processing data in native languages.

Over 50 different national, multinational, and vendor-specific character sets including the most popular single-byte and multibyte encodings, plus Unicode, are supported as the database storage character set. Cache operations support some database character sets that are

compatible with the Oracle Database. The connection character set can be defined to enable an application running in a different encoding to communicate to a TimesTen database; character set conversion between the application and the database occurs automatically and transparently.

TimesTen offers linguistic sorting capabilities that handle the complex sorting requirements of different languages and cultures. More than 80 linguistic sorts are provided. They can be extended to enable the application to perform case-insensitive and accent-insensitive sorting and searches.

See Globalization Support in *Oracle TimesTen In-Memory Database Operations Guide*.

Database Connectivity

TimesTen supports direct and client/server connection options so that users can choose the best tradeoff between performance and functionality for their applications.

- A *direct connection* connects an application to a database where both exist on the same system.
- A *client/server connection* accommodates connections from remote client machines to databases across a network.

From an application's perspective, the TimesTen API is identical whether it is a direct connection or a client/server connection.

See TimesTen Connection Options for overall information on connection options. See Database Connections and Connecting to a Database in the *Oracle TimesTen In-Memory Database Scaleout User's Guide* for details specific to TimesTen Scaleout.

Load Data From an Oracle Database Into a TimesTen Table

You can load the results of a SQL query from a back-end Oracle database into a single table on TimesTen. TimesTen provides tools that run a user-provided `SELECT` statement on the Oracle database and load the result set into a table on TimesTen.

TimesTen provides the following methods to accomplish these tasks:

- Use cache operations, which provide the connection and transfer of data between an Oracle database and a TimesTen database. You can cache Oracle Database data in a TimesTen database within cache groups. A cache group in a TimesTen database can cache a single Oracle Database table or a group of related Oracle Database tables.
- The `ttIsql` utility is an interactive SQL utility. The `ttIsql createandloadfromoraquery` command, once provided the TimesTen table name and the `SELECT` statement, automatically creates the TimesTen table, runs the `SELECT` statement on the Oracle database, and loads the result set into the TimesTen table.
- The `ttTableSchemaFromOraQueryGet` built-in procedure evaluates the user-provided `SELECT` statement to generate a `CREATE TABLE` statement that you can run to create a table on TimesTen. This table would be appropriate to receive the result set from the `SELECT` statement. The `ttLoadFromOracle` built-in procedure runs the `SELECT` statement on the Oracle database and loads the result set into the TimesTen table.

System Monitoring

You can use system tables, system views, and the `ttStats` utility for system monitoring and reporting for both TimesTen Classic and TimesTen Scaleout. The following sections describe system monitoring and reporting tools:

- System Monitoring Through System Tables and Views
- System Monitoring for TimesTen Classic
- System Monitoring for TimesTen Scaleout

System Monitoring Through System Tables and Views

TimesTen stores metadata (information about the contents of your database) in system tables in your database. TimesTen also provides system views that allow you to use SQL to query information.

Use the `ttIsql alltables` to display a list of all system and user tables. Use the `ttIsql allviews` command to display a list of all system and user views. See ttIsql in the *Oracle TimesTen In-Memory Database Reference*.

See System Tables and Views in the *Oracle TimesTen In-Memory Database System Tables and Views Reference*.

System Monitoring for TimesTen Classic

Users have the following options for system monitoring and reporting.

- You can use the `ttStats` utility to monitor and display database performance metrics. It generates HTML reports from performance snapshots at user-specified intervals.

  > **Note:**
  >
  > System statistics are collected and stored in the `SYS.SYSTEMSTATS` table; the information is used by various TimesTen utilities and monitoring facilities.

- You can use the Oracle Enterprise Manager System Monitoring Plug-In for TimesTen In-Memory Database that provides a graphical user interface to monitor database metrics and performance. You can also view reports on the collected metric information, which is useful in diagnosing and troubleshooting database performance issues.
- You can use the `ttStatsConfig`, `ttSQLCmdCacheInfo`, and `ttSQLExecutionTimeHistogram` built-in procedures to measure and display runtime statistics for SQL operations to determine the performance of SQL statements.

System Monitoring for TimesTen Scaleout

There are options for system monitoring and reporting for your grid and database.

> **Note:**
>
> See Monitoring TimesTen Scaleout in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

- You can use the `ttStats` utility enables you to monitor database metrics (statistics, states, and other information) or take and compare snapshots of metrics. It generates HTML reports from performance snapshots at user-specified intervals. See Using the ttStats Utility in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

  > **Note:**
  >
  > System statistics are collected and stored in the `SYS.SYSTEMSTATS` table; the information is used by various TimesTen utilities and monitoring facilities.

- You can collect various logs from every host that is part of your grid. These logs are useful for troubleshooting errors that you may encounter while using your grid or database. See Collecting Grid Logs in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.
- You can monitor the management instances. See Monitoring the Management Instances in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.
- You can use SQL Developer to create, manage, and explore a grid and its components. Additionally, you can also browse, create, edit and drop particular database objects; run SQL statements and scripts; manipulate and export data; view and create reports; and view database metrics. See Using SQL Developer to Work With TimesTen Scaleout in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Administration and Utilities

Utility programs are explicitly invoked by users, scripts, or applications to perform services such as interactive SQL, bulk copy, backup and restore, database migration and system monitoring.

TimesTen supports typical database utilities such as the following:

- Interactive SQL (`ttIsql`).
- Migrate (`ttMigrate`) provides a way to quickly move data between different major versions of TimesTen.
- Many administrative activities are available through SQL statements and system views. TimesTen also uses SQL statements to set up materialized views.

TimesTen Scaleout provides database management through the `ttGridAdmin` utility.

TimesTen Classic also supports typical database utilities such as the following:

- Backup and restore (`ttBackup` and `ttRestore`).
- Copy data between different database systems.
- Using SQL statements to set up replication and caching from an Oracle database.

TimesTen built-in procedures and C language functions enable programmatic control over TimesTen operations and settings. TimesTen command-line utilities enable users to monitor the

status of connections, locks, replication, and so on. Status can also be obtained using SQL `SELECT` queries on the system tables in the TimesTen schema.

See TimesTen Administration.

TimesTen Scaleout Specific Features

In addition to the TimesTen general features, the following features are supported within TimesTen Scaleout

- High Availability Features for TimesTen Scaleout
- Transparent Data Distribution
- Online Elastic Scalability
- Automatic High Availability Through K-Safety
- Single Point for Administration and Monitoring

High Availability Features for TimesTen Scaleout

The architecture for TimesTen Scaleout provides high performance and supports high availability.

TimesTen Scaleout enables you to create a grid of interconnected instances running on one or more hosts. You can create a database hosted in the grid and the data stored in that database is distributed across the instances of the grid. Each instance contains one piece (an element) of every database hosted in the grid.

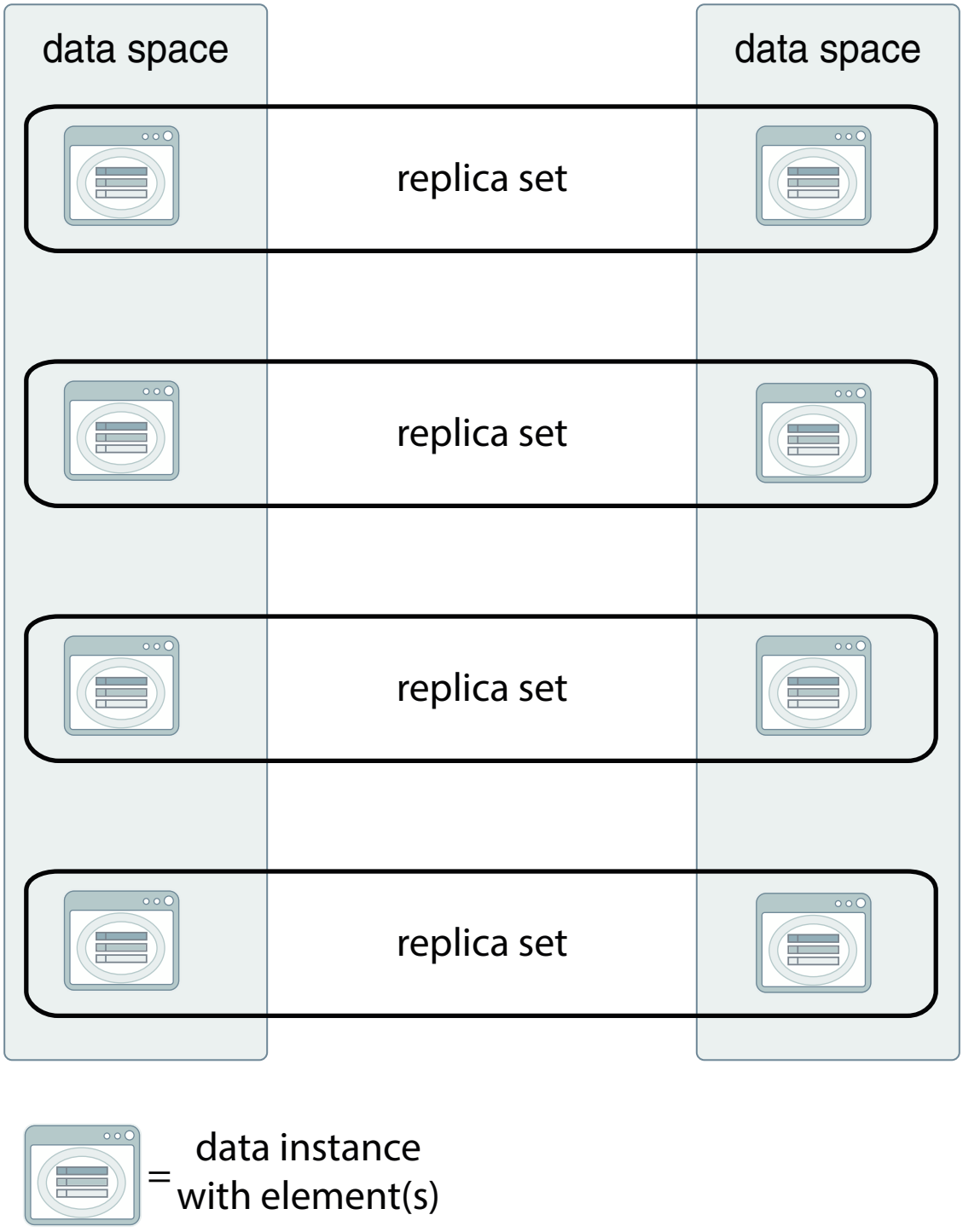
Figure 1-2 highlights this portion of the architecture.

- TimesTen Scaleout provides high availability by enabling you to specify that the system maintain more than one copy of every item of data within a database, known as K-safety. The number of copies of data is referred to as the *k*-factor. Your choice to maintain more than one copy protects you from data loss in the event of a single failure. So a grid with *k*=1 does not provide high availability (as there is only one copy of the data); however, a grid with *k* > 1 provides high availability.

  Each copy of the database is logically contained within a data space, which logically groups the instances that contain one entire copy of a database. There are always as many data spaces as the grid *k*-factor.
- TimesTen Scaleout spreads the work for the database across data instances in parallel, which computes the results of your SQL statements faster. the data in your database is distributed into elements.
- Your application can connect to any data instance in the grid and transparently access all of the data in the database without having to know where specific data is located.
- A replica set is a set of database elements with identical contents (the multiple copies resulting from the specified *k*-factor). Each replica set always contains *k* elements. The separate elements within a replica set are located across separate data spaces. If one element fails, your connection can be rerouted to the other element in the replica set, if it is still available.
- You can add or remove instances from your grid to:
  - Expand or shrink the storage capacity of your database as necessary.
  - Expand or shrink the computing resources of your database to meet the performance requirements of your applications.

Figure 1-2 shows a database within the grid where the *k*-factor is set to 2.

Figure 1-2 Performance and High Availability Architecture Within TimesTen Scaleout



See Architectural Overview of TimesTen Scaleout in this guide and TimesTen Scaleout Architecture in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Transparent Data Distribution

While TimesTen Scaleout distributes your data across multiple instances, applications do not need to know how data is distributed. When an application connects to any instance in the grid, it has access to all of the data of the database without having to know the location of specific data.

Knowledge about the distribution of data is never required in TimesTen Scaleout, but it can be used to tune the performance of your application. You can use this knowledge to exploit locality where possible.

See Data Transparency in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Online Elastic Scalability

TimesTen Scaleout enables you to add or remove instances in order to control both performance and the storage capacity of your database.

Adding instances improves the throughput of your workload by providing the additional computing resources of the hosts running those instances. If your business needs change, then removing instances (and their hosts) enables you to meet your targets with fewer resources.

See Scalability in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Automatic High Availability Through K-Safety

TimesTen Scaleout provides high availability and fault tolerance when you have multiple copies of data located across separate hosts with K-safety (`k`).

When one copy of the data is unavailable due to a software error, SQL statements are automatically redirected to the other copy of the data (if possible). In the meantime, TimesTen Scaleout synchronizes the data on the failed system with the rest of the database.

See TimesTen Scaleout Specific Features and High Availability and Fault Tolerance in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Single Point for Administration and Monitoring

You do not need to log onto every host within a grid in order to perform management activities. Instead, you conduct all management activity from a single management instance using the `ttGridAdmin` utility.

Use the `ttGridAdmin` utility to define, deploy, and check on the status of each database.

You can also use the `ttGridRollout` utility or the Oracle SQL Developer GUI (both of which use the `ttGridAdmin` utility under the covers to run all requests) to facilitate creating, deploying, and managing your grid.

See Centralized Management in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

TimesTen Classic Specific Features

In addition to the TimesTen general features, the following features are supported within TimesTen Classic.

- High Availability Features for TimesTen Classic
- Data Replication Between Servers
- Transaction Log API (XLA)
- Automatic Data Aging

High Availability Features for TimesTen Classic

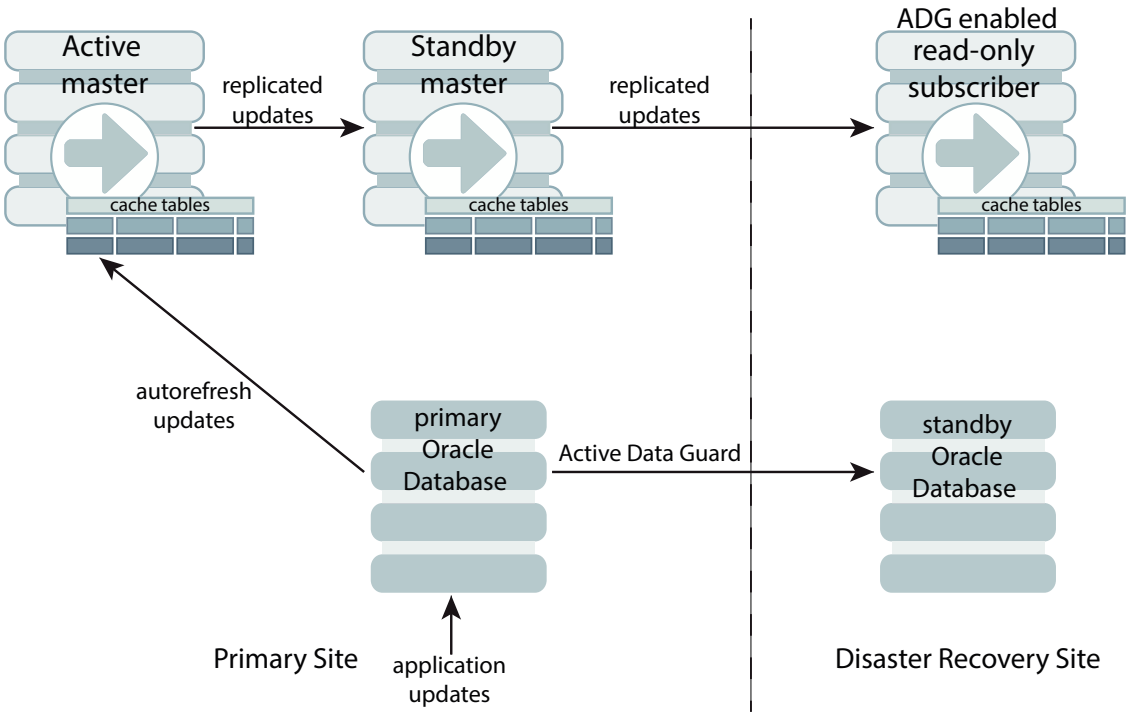
TimesTen Classic has several features that provide performance and high availability.

- TimesTen Classic *replication* enables you to achieve near-continuous availability or workload distribution by sending updates between two or more hosts. An active standby pair replication scheme includes an active database, a standby database, and optional read-only subscriber databases. In Figure 1-3, the active and standby databases can be located at a primary site, while a read-only subscriber is located at a disaster recovery site.
- Cache operations enable you to cache portions of an Oracle database in a TimesTen database in tables within a *cache group*. In Figure 1-3, tables cached on the Oracle database can be cached as read-only copies in TimesTen. TimesTen can automatically propagate changes from the Oracle tables to the cache group in the TimesTen database.

  In Figure 1-3, there are two Oracle databases set up within an Active Data Guard (ADG) configuration: one at the primary site and the other at the disaster recovery site. ADG propagates any data changes made on the primary Oracle database to the standby Oracle database. When used in conjunction with cache operations, the integration of ADG within TimesTen ensures that only changes that have been propagated to the standby Oracle database are refreshed to appropriate cache groups. In the event of a failure of the primary Oracle database, we switch over to the standby Oracle database. After which, cache operations also switch over and continue with automatic refresh while remaining consistent with the Oracle database.

  There are other recovery methods for if the standby Oracle database fails or if the entire primary site fails. See Recovery after failure when using asynchronous Active Data Guard in the *Oracle TimesTen In-Memory Database Cache Guide*.

Figure 1-3 Performance and High Availability Configuration for TimesTen Classic



See Cached Data and Replication.

Data Replication Between Servers

TimesTen Classic provides replication schemes that enable data replication between servers for high availability and load sharing.

Data replication configurations can be active-standby or active-active, using asynchronous or synchronous transmission, with conflict detection and resolution and automatic resynchronization after a failed server is restored. See Data Replication Within TimesTen Classic.

Transaction Log API (XLA)

TimesTen Classic provides an API that enables applications to monitor update activities in order to generate actions outside the database. This capability is provided by the Transaction Log API (XLA), which enables applications to monitor update records as they are committed and take various actions based on the detected updates.

For example, an XLA application can apply the detected updates to another database, which could be TimesTen or a file system-based RDBMS. Another type of XLA application can notify subscribers that an update of interest has taken place. This API is supported for C, Java (JMS/XLA) and C++ (TTClasses).

TimesTen Classic provides materialized views that can be used with XLA to enable notification of events described by SQL queries. The primary purpose of XLA is to be a high performance, asynchronous alternative to triggers.

See Detect Transaction Modifications With the Transaction Log API and *Oracle TimesTen In-Memory Database C Developer's Guide*.

Automatic Data Aging

Data aging removes data that is no longer needed. TimesTen offers automatic data aging for TimesTen database tables and cache tables.

The two types of automatic data aging capability for TimesTen database tables and cache tables are:

- Time-based data aging based on timestamp values: Removing old data based on a time value. For example, you can remove yesterday's price list or remove detailed records that are more than 2 days old
- Usage-based data aging based on the least recently used (LRU) algorithm: Removing old data that has been least recently used. For example, you can remove profiles and preferences of users who have logged out from the system.

See Implementing Aging in Your Tables in *Oracle TimesTen In-Memory Database Operations Guide* and Implementing Aging in a Cache Group in *Oracle TimesTen In-Memory Database Cache Guide*.

Cache Specific Features

TimesTen provides support for an updatable cache for Oracle database data within a cache group. Cache operations offload computing cycles from Oracle databases and enable responsive and scalable applications.

A cache group in TimesTen:

- Loads a subset of the Oracle database tables into a TimesTen database.
- Can be configured to propagate updates in both directions and to automate passthrough of SQL requests for uncached data.
- Automatically resynchronizes data after failures.

TimesTen provides multiple types of cache groups that cache Oracle database tables with automatic data synchronization.

See Caching in TimesTen.

2

Using TimesTen

TimesTen can be used as:

- The *primary database* for applications, where all data needed by the applications resides in the TimesTen database.
- A *service* for accelerating performance-critical points in an architecture. For example, providing persistence and transactional capabilities to a message queuing system might be achieved by using TimesTen as the repository for the messages.
- A *data integration point* for multiple data sources on top of which new applications can be built. For example, an organization may have large amounts of information stored in several data sources, but only subsets of this information may be relevant to running its daily business. A suitable architecture would be to pull the relevant information from the different data sources into one TimesTen operational database to provide a central repository for the data of immediate interest to the applications.

Users can take advantage of the integrated high performance parallel data replication capability to add high availability and disaster recovery capabilities to applications.

Uses for TimesTen Scaleout

TimesTen Scaleout is used for multiple-instance environments and distributed databases. TimesTen Scaleout provides fast access, fault tolerance, and high availability for in-memory data.

With TimesTen Scaleout, you can:

- Create a grid that is a set of interconnected instances installed on one or more hosts.
- Maintain one or more copies of your data. Your choice to maintain more than one copy protects you from data loss in the event of a single failure.
- Distribute the data of each database across the instances in the grid in a highly available manner using a shared-nothing architecture.
- Connect applications to your database with full access to all the data, no matter what the distribution of the data is across the database.
- Add or remove instances from your grid to:
  - Expand or shrink the storage capacity of your database as necessary.
  - Expand or shrink the computing resources of your database to meet the performance requirements of your applications.

See Overview of TimesTen Scaleout in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

TimesTen Scaleout Application Scenario

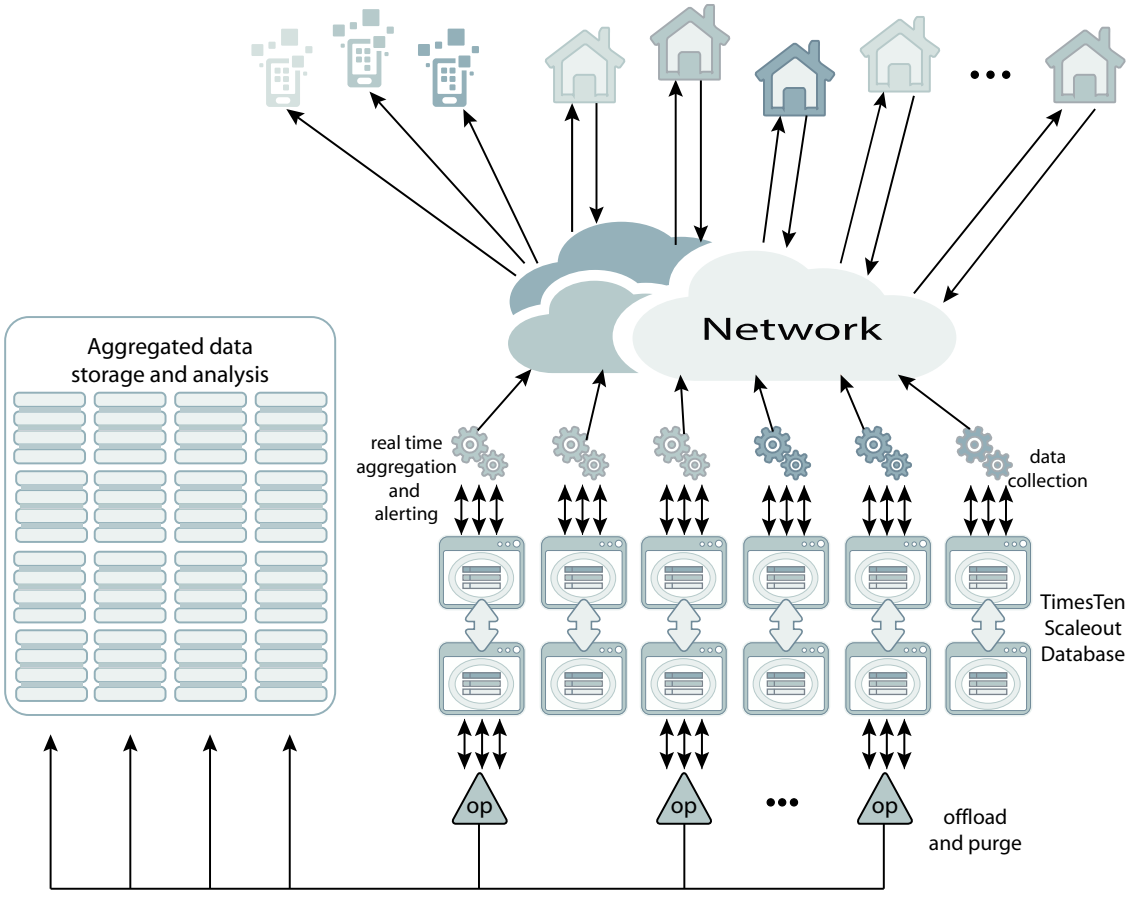
A typical use case scenario for TimesTen Scaleout is an Internet-of-Things (IoT) application.

TimesTen Scaleout is used to:

- Capture semi real-time data (sensor readings, geolocation data, telemetry, and so on) from a vast array of connected devices.
- Aggregate and analyze data in real-time (for alerting purposes) before offloading data to other systems for further reporting and analysis.

The Internet is pervasive as more and more devices are connected (such as smart homes, smart phones, tablets, cars, domestic appliances, utility meters, exercise devices, GPS trackers, RFID tags, and so on). Many services need to efficiently capture and process huge volumes of data generated in a real-time by these devices.

Figure 2-1 Using TimesTen Scaleout for an Internet-of-Things Application



A TimesTen Scaleout application example illustrates how a vendor of smart home technology uses TimesTen Scaleout to capture sensor data (temperature, humidity, CO2 levels, device events). Once captured, the data is aggregated and analyzed in order to generate real-time alerts for anomalous conditions and then the aggregated data is offloaded to other systems for archival storage, in depth analysis, and so on. Once offloaded, the data is purged from the database.

- Capture: Sensor data collected from the smart home devices is sent over the Internet to the data collection applications running in the same vicinity as the database. These applications insert and update data in the database based on the received data.
- Aggregate and analyze: Real-time aggregation and alerting applications perform initial processing on the data as it arrives. If the application detects any important events, then the application sends alerts to the smart home devices, user's smartphone applications, and so on.

Offload and purge applications move historical aggregated data that is no longer needed online to storage, for long term storage and analysis. Once moved into storage, the aggregated data and underlying raw data is purged from the database.

TimesTen Scaleout is ideal for this type of application:

- High throughput and low latency enables TimesTen Scaleout to cope with a heavy read-write workload.
- Fault tolerant architecture enables TimesTen Scaleout to deliver continuous uptime even in the event of hardware or software failures.
- Elastic scalability features enable the storage and processing capacity of the database to dynamically increase while remaining online.
- Support for a broad range of industry standard languages and APIs makes building different application components easy for developers.

Uses for TimesTen Classic

TimesTen Classic provides a memory-optimized relational database that gives applications the best response time and high throughput.

TimesTen Classic:

- Can be used for a single-instance environment and database.
- Can be used to create one or more in-memory, SQL relational, ACID-complaint databases.
- Supports high availability for the in-memory database through transactional replication.

TimesTen Classic Application Scenario

A Quote service application is an example of a TimesTen Classic scenario. This quote service illustrates how TimesTen Classic can be integrated as part of a data management solution.

A financial services company is adding a quote and news service to its online trading facility. The quote service reads an incoming news wire from a major market data vendor and make a subset of the data available to trading applications that manage the automated trading operations for the company. The company plans to build an infrastructure that can accommodate future expansion to provide quotes, news, and other trading services to retail subscribers.

The quote service application uses the database to store stock quotes from a data feed for access by program trading applications. Quote data is collected from the data feed and published on a message bus. The data is read from the message bus and stored in the database, where it is accessed by the program trading applications.

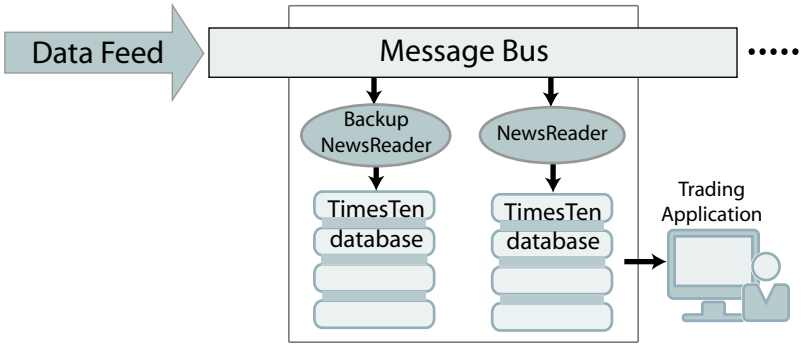
The quote service includes a *NewsReader* process that reads incoming data from a message bus that is constantly fed data from a news wire. Each NewsReader is paired with a backup NewsReader that independently reads the data from the bus and inserts it into a separate database. In this way, the message bus is used to fork incoming data to two databases for

redundancy. In this scenario, forking the data from the message bus is more efficient than using TimesTen replication.

One NewsReader makes the stock data available to a trading application, while the other serves as a hot standby backup to be used by the application if a failure occurs. The current load requires four NewsReader pairs, but more NewsReader pairs can be added in the future to scale the service to deliver quotes to other types of clients over the Web or cellular phone.

Figure 2-2 shows the configuration for capturing data from a message bus and feeding it to NewsReaders.

Figure 2-2 Capturing Feed Data From a Message Bus

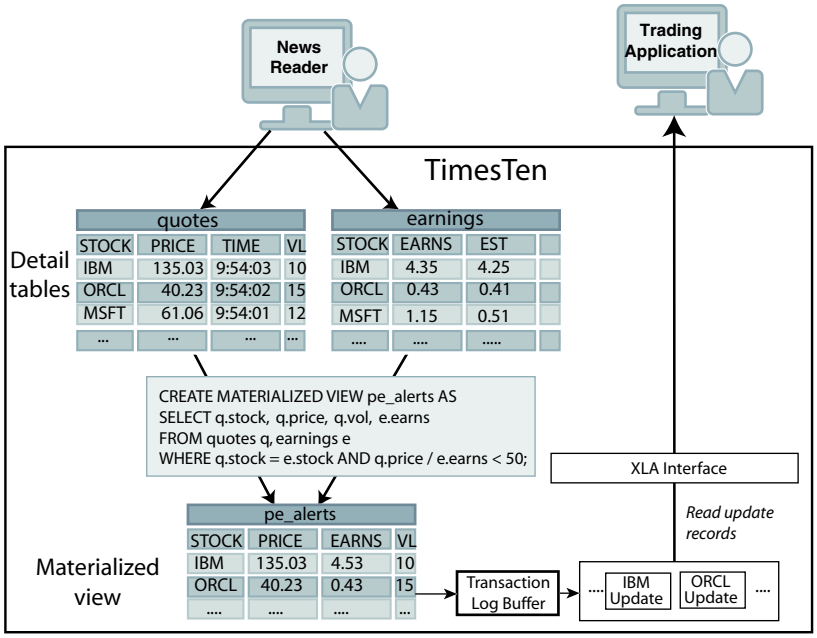


As shown in Figure 2-3, the NewsReader updates stock price data in a `QUOTES` table in the database. Less dynamic earnings data is updated in an `EARNINGS` table. The `STOCK` columns in the `QUOTES` and `EARNINGS` tables are linked through a foreign key relationship.

The purpose of the trading application is to track only those stocks with PE ratios below 50, then use internal logic to analyze the current stock price and trading volume to determine whether to place a trade using another part of the trading facility. For maximum performance, the trading application implements an event facility that uses the Transaction Log API (XLA) to monitor the transaction log for updates to the stocks of interest. See Detect Transaction Modifications With the Transaction Log API.

To provide the fastest possible access to such updates, the company creates a materialized view, named `PE_ALERTS`, with a `WHERE` clause that calculates the PE ratio from the `PRICE` column in the `QUOTES` table and the `EARNS` column in the `EARNINGS` table. By using the XLA event facility to monitor the transaction log for price updates in the materialized view, the trading application receives alerts only for those stocks that meet its trading criteria.

Figure 2-3 Using Materialized Views and XLA



Uses for Cache in TimesTen

Cache is supported in both TimesTen Scaleout and TimesTen Classic and can be used for read-only or updatable data.

The features for cache in TimesTen are:

- A *read-only cache*. Oracle Database data can be cached in a read-only cache group. Read-only cache groups are automatically refreshed when the Oracle database tables are updated. A read-only cache group provides fast access to reference data such as look-up tables and subscriber profiles.
- An *updatable cache*. Oracle Database data can be cached in updatable cache groups. Transactions on the cache groups can be committed synchronously or asynchronously to the associated Oracle database tables.
- A *data manager* for specific tasks in an overall workflow in collaboration with a file system-based RDBMS like the Oracle Database. For example, a phone billing application may capture and store recent call records in the TimesTen database while storing information about customers, their billing addresses and credit information in an Oracle database. It can also age and keep archives of all call records in the Oracle database. Thus, the information that requires immediate access is stored in the TimesTen database while the information needed for longer-term analysis, auditing, and archival is stored in the Oracle database.
- A *scalable cache*. Oracle Database data can be cached in multiple instances of TimesTen running on different machines to provide scalability. You can configure a dynamic distributed cache in which records are loaded automatically and aged automatically.
- An integrated method for *high availability* and *disaster recovery*. TimesTen replication is tightly integrated with cache features enabling customers to deploy highly available cache configurations. Cache functionality also integrates with Oracle Database high availability features such as Oracle RAC and Oracle Data Guard to provide seamless cross-tier high availability and disaster recovery capabilities.

See Caching in TimesTen and Replication.

Cache Application Scenario

One example of using a cache group is a Caller usage metering application that illustrates how a cache group can store metering data on the activities of cellular callers.

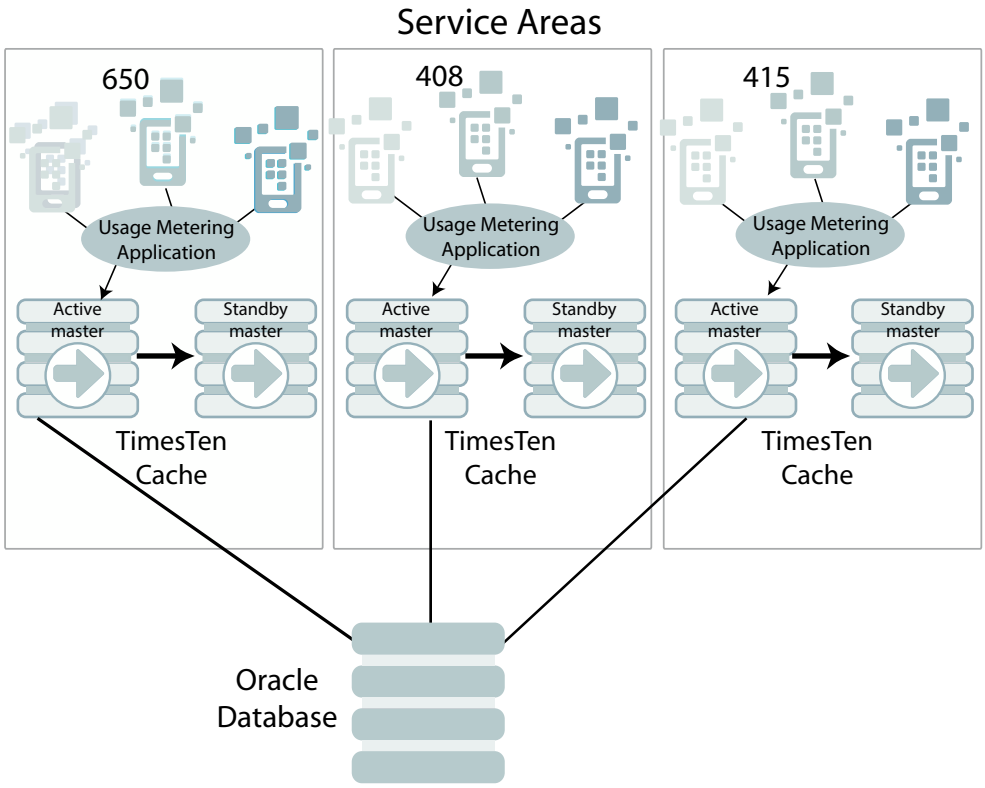
A wireless communications company has a usage metering application that keeps track of the duration of each cellular call and the services used. For example, if a caller makes a regular call, a base rate is applied for the duration of the call. If a caller uses special features (like roaming), extra charges are applied.

The usage metering application must efficiently monitor up to 100,000 concurrent calls, gather usage data on each call, and store the data in a central database for use by other applications that generate bills, reports, audits, and so on. Thus, metering data is collected from multiple TimesTen databases distributed throughout a service area and archived in a central Oracle database for use by a central billing application.

The company uses TimesTen databases in an active standby pair to store the caller data that is of immediate interest to the usage metering application and to warehouse all of the other data in the Oracle database. The company distributes multiple instances of the usage metering application on individual nodes throughout its service areas. For maximum performance, each usage metering application connects to its local TimesTen database by an ODBC direct driver connection.

Figure 2-4 shows the configuration.

Figure 2-4 Distributed Caching of Usage Data



A usage metering application and a TimesTen database are deployed on each node to handle the processing for calls beginning and terminating at different geographical locations delineated by area code. For each call, the local node stores a separate record for the beginning and the termination of a call. This is because the beginning of a cellular call might be detected by one node and its termination by another node.

Transactions that impact revenue (inserts and updates) must be durable. To ensure data availability, each TimesTen database is configured as an active-standby replicated pair using TimesTen replication.

Each time a customer makes, receives or terminates a cellular call, the application inserts a record of the activity into the *Calls* table in the TimesTen database. Each call record includes a timestamp, unique identifier, originating host's IP address, and information on the services used.

In this scenario, the `CALLS` table is configured for write through caching; as data is inserted, updated, or deleted in the table in TimesTen, the changes are automatically propagated (in real-time) to the underlying Oracle database. After the call records have been successfully propagated to the Oracle database, they are deleted from the TimesTen databases (but not from the Oracle database) by an automatic time-based aging process.

3
TimesTen Architecture

This chapter includes the following topics:

Architectural Overview

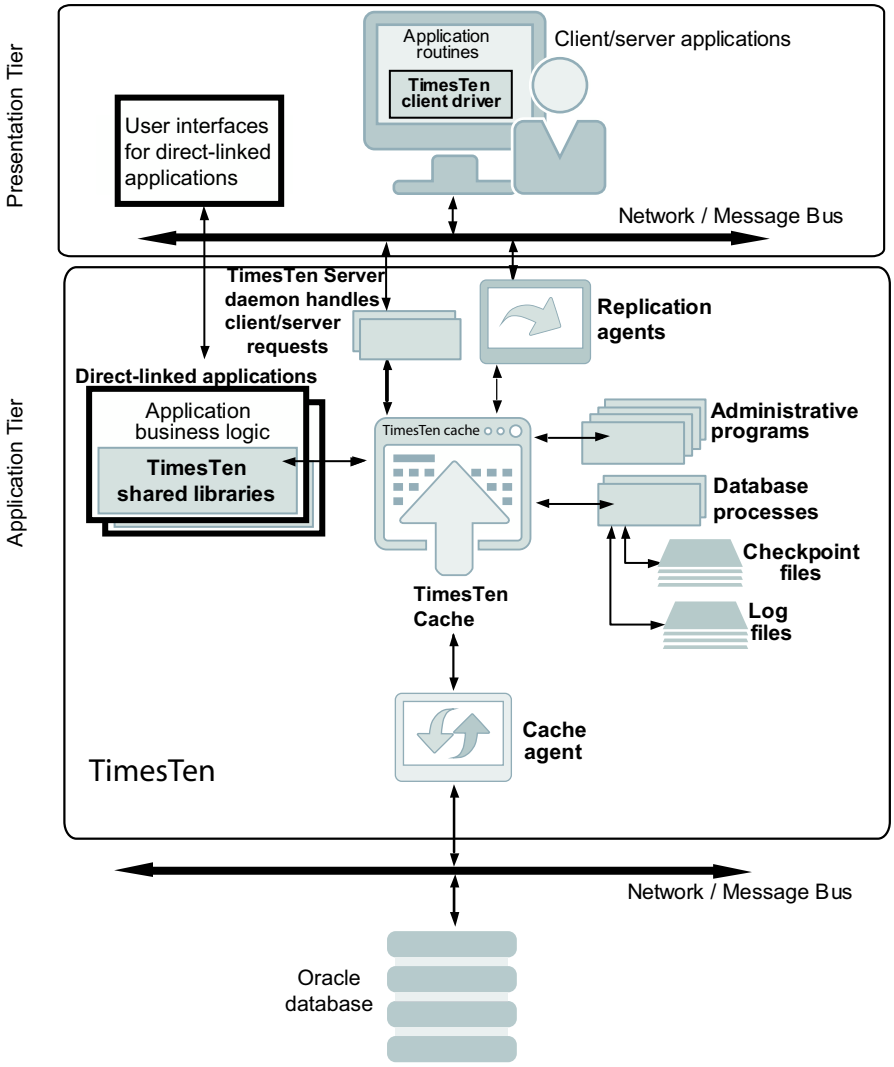
The architecture for TimesTen Classic and TimesTen Scaleout are described in the following sections:

Architectural Overview of TimesTen Classic and Cache

This section describes the architecture of TimesTen Classic and cache.

The architecture of TimesTen Classic is the same as the architecture of cache except that the Oracle database and cache agent are not included. Figure 3-1 shows the architecture of cache.

Figure 3-1 TimesTen Classic and Cache Architecture



The architectural components include shared libraries, memory-resident data structures, database processes, and administrative programs. The application can connect to the TimesTen database by direct link and by client/server connections.

Replication agents receive information from master databases and send information to subscriber databases. The *cache agent* performs all asynchronous data transfers between cache groups in the TimesTen and the Oracle databases.

See TimesTen Architecture.

Architectural Overview of TimesTen Scaleout

TimesTen Scaleout enables you to create a grid that is a set of interconnected instances installed on one or more hosts. TimesTen Scaleout enables you to distribute the data of a database across this grid.

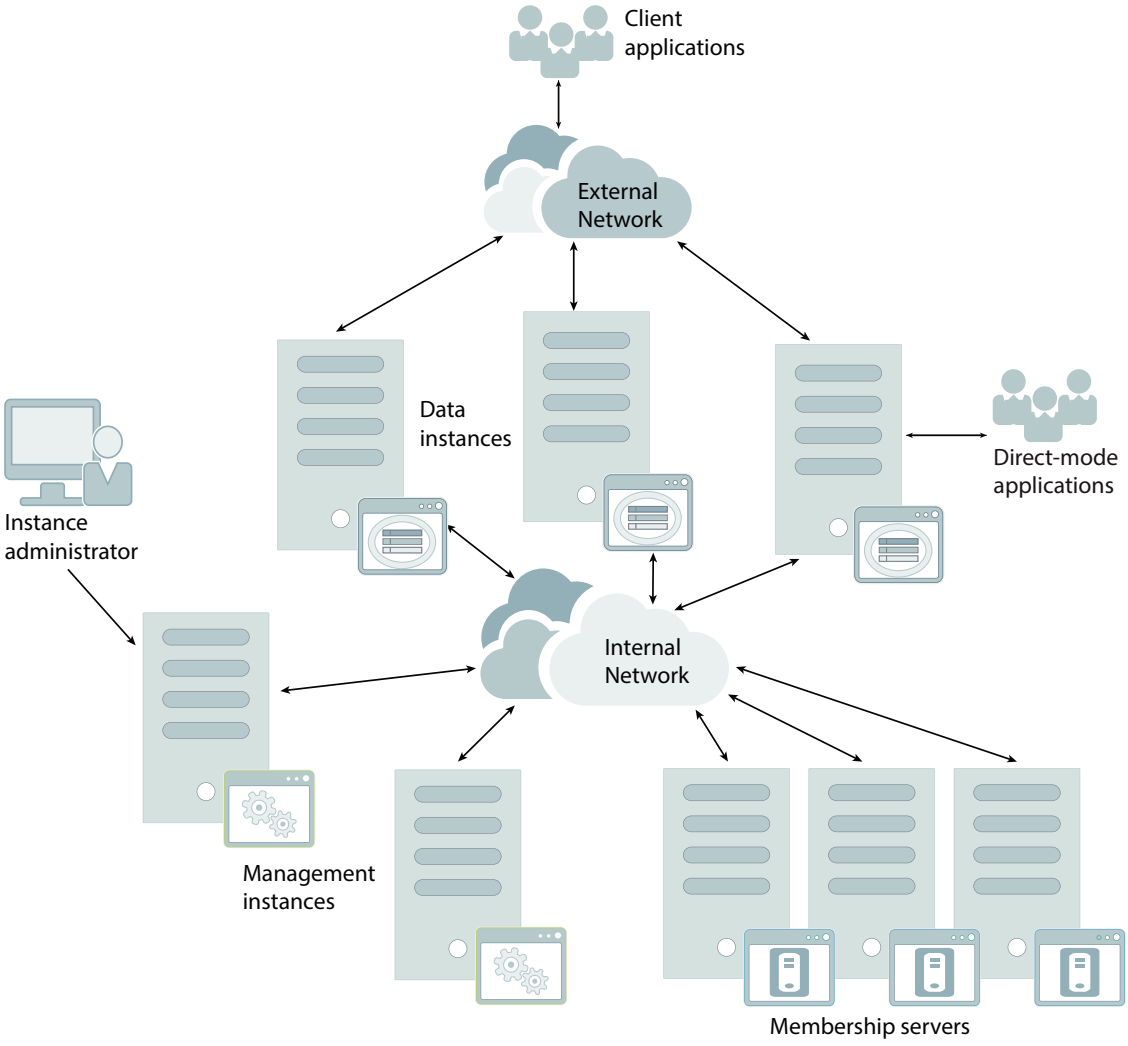
- You can create one or more in-memory, SQL relational, ACID-complaint databases.

  The architectural components for each database include shared libraries, memory-resident data structures, database processes, and administrative programs. The application can

connect to the TimesTen database by direct link and by client/server connections. These components are described in subsequent sections.

- *Data instances* (in which data is contained and managed) run SQL statements and PL/SQL blocks. A grid distributes the data within each database across data instances.
- You create one or two *management instances* through which the grid is managed. You manage all data instances through the active management instance.
- Set up a *membership service* to track which data instances are operational at any moment. The membership service consists of three or more *membership servers*.
- You can connect applications to your database with full access to all the data, no matter what the distribution of the data is across the database.

Figure 3-2 TimesTen Scaleout Grid Structure



See TimesTen Scaleout Architecture in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Shared Libraries

The routines that implement the TimesTen functionality are embodied in a set of shared libraries that developers link with their applications and run as a part of the application's process.

This shared library approach is in contrast to a more conventional RDBMS, which is implemented as a collection of daemon processes to which applications connect, typically over a client/server network. Applications can also use a client/server connection to access a TimesTen database, though in most cases the best performance can be realized with a directly linked application. See TimesTen Connection Options.

Memory-Resident Data Structures

The TimesTen database resides entirely in main memory at runtime.

The database is maintained in shared memory regions provided by the operating system and contains all user data, indexes, system catalogs, transaction log buffers, and temporary space. Multiple applications can share one database, and a single application can access multiple databases on the same system.

Database Processes

TimesTen initiates separate background processes to each database to perform operations:

- TimesTen Daemon
- Subdaemons

TimesTen Daemon

The TimesTen daemon starts when TimesTen is installed. This main daemon runs in the background. The instance administrator must manually start and stop the daemon after each system reboot or the `root` user can start the daemon by running the daemon startup script.

The *TimesTen daemon* performs the following functions:

- Manage shared memory access
- Coordinate process recovery
- Keep management statistics on what databases exist, which are in use, and which application processes are connected to which databases
- Manage RAM policy
- Start replication processes (if requested), the TimesTen Server and the cache agent (if enabled).

Application developers do not interact with the daemon directly. No application code runs in the daemon and application developers do not generally have to be concerned with it. Application programs that access TimesTen databases communicate with the daemon transparently using TimesTen internal routines.

See Working with the TimesTen Daemon in the *Oracle TimesTen In-Memory Database Operations Guide*.

Subdaemons

The main TimesTen daemon spawns *subdaemons* dynamically as they are needed.

TimesTen uses subdaemons to perform the following:

- Manage databases
- Flush the transaction log buffer to the file system
- Perform periodic checkpoints in the background for the active database
- Load the database into memory from a checkpoint file on the file system
- Implement the data aging policies of various tables
- Detect and handle deadlocks
- Roll back transactions for abnormally terminated direct-mode applications
- Perform required background processing for the database
- Recover the database if it needs to be recovered after loading it into memory

See Managing Subdaemons in the *Oracle TimesTen In-Memory Database Operations Guide*.

TimesTen Connection Options

TimesTen supports direct, driver manager, and client/server connection options so that users can choose the best tradeoff between performance and functionality for their applications.

From an application's perspective, the TimesTen API is identical whether it is a direct connection, driver manager connection, or a client/server connection.

Applications can connect to a TimesTen database in one of the following ways:

- Direct Connection
- Client/Server Connection
- Driver Manager Connection

For more information about connecting to a TimesTen Classic database, see Managing TimesTen Databases, Working With the TimesTen Client and Server and Connecting to TimesTen with ODBC and JDBC Drivers in the *Oracle TimesTen In-Memory Database Operations Guide*.

For details on connecting to a grid using TimesTen Scaleout, see Database Connections and Connecting to a Database in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Direct Connection

An application using a *direct connection* runs on the same system as the database. In a direct connection, the ODBC driver attaches the shared memory region of the TimesTen database into the application's process address space.

The application uses the direct driver to access the memory image of the database. Because no inter-process communication (IPC) of any kind is required, a direct connection provides extremely fast performance and is the preferred way for applications to access the TimesTen database.

Applications that use direct connections must run in the environment of the TimesTen instance that provides the database. When using TimesTen Scaleout applications can run in any data instance.

The ODBC direct driver is a library of ODBC and TimesTen routines that implement the database engine used to manage the database. Applications using other APIs use the appropriate API library, which then in turn uses the TimesTen ODBC driver.

Client/Server Connection

The *TimesTen client driver* and *TimesTen Server daemon* processes accommodate connections from remote client machines to databases across a network.

- Applications on a client machine issue ODBC, JDBC or OCI calls. These calls access a local ODBC client driver that communicates with the TimesTen instance. The TimesTen instance, in turn, issues native ODBC requests to the ODBC direct driver to access the TimesTen database.
- The TimesTen server daemon manages incoming connections from remote client applications. Its behavior is much like the TimesTen daemon for local applications, but it allocates a server child process to access the database on behalf of the client.

Traditional client/server access is supported for functions such as reporting, or when a large number of application-tier platforms must share access to a common in-memory database.

All exchanges between client and server are sent over a TCP/IP connection. If the client and server reside on separate hosts in the internal network, they communicate by using sockets and TCP/IP. If both the client and server reside on the same machine, they can communicate more efficiently by using direct connections.

- Client applications communicate with the TimesTen instance that provides the database.
- With TimesTen Scaleout, an application using a client/server connection may run on a data instance or on any host with access to the external network. Client applications are automatically connected to a working data instance. See Database Connections in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

See Working With TimesTen Databases in ODBC in the *Oracle TimesTen In-Memory Database C Developer's Guide* and Working With TimesTen Databases in JDBC in the *Oracle TimesTen In-Memory Database Java Developer's Guide*.

Driver Manager Connection

Applications can connect to the TimesTen database through an ODBC *driver manager*. A single application can use a driver manager to link with multiple different drivers.

The driver manager enables applications to operate independently of the database and to use interfaces that are not directly supported by TimesTen. An application uses an ODBC driver manager when it wants to use both direct and client-server connections concurrently to a database.

- The TimesTen driver manager (provided as part of TimesTen) provides a transparent, low overhead option for TimesTen drivers. The TimesTen driver manager enables ODBC applications to use direct and client-server connections from the same process to a TimesTen database. The TimesTen driver manager supports XLA, the Routing API, the TimesTen Utility API and TimesTen ODBC extensions. See Introduction to the TimesTen Driver Manager in the *Oracle TimesTen In-Memory Database C Developer's Guide*.
- A generic ODBC driver manager provides support for ODBC applications written for a different ODBC versions or for multiple RDBMS products with ODBC interfaces. Windows

provides a standard ODBC driver manager. For Linux or UNIX, you have a choice of open source or commercial driver managers.

Note that there are performance considerations in using an ODBC driver manager. The performance considerations are minimal with the TimesTen driver manager.

See Connecting to TimesTen With ODBC and JDBC Drivers in the *Oracle TimesTen In-Memory Database Operations Guide*.

Checkpoint and Transaction Log Files

Checkpoint files contain an image of the database in persistent storage on the file system. TimesTen uses dual checkpoint files in case the system fails while a checkpoint operation is in progress.

TimesTen captures the changes to a database in *transaction log files*. TimesTen periodically writes to persistent storage on the file system. If a database needs recovery, TimesTen merges the most recent database checkpoint file on the file system with the completed transactions still in the transaction log files.

See Data Availability and Integrity.

Cached Data

When you cache portions of an Oracle database in a TimesTen database, a *cache group* is created to hold the cached data.

A cache group is a collection of one or more tables arranged in a logical hierarchy by using primary key and foreign key relationships. Each table in a cache group is related to an Oracle database table. A cache table can contain all rows and columns or a subset of the rows and columns in the related Oracle database table. You can create or modify cache groups by using SQL statements or by using Oracle SQL Developer. Cache groups support these features:

- Applications can read from and write to cache groups.
- Cache groups can be refreshed from the Oracle database automatically or manually.
- Updates to cache groups can be propagated to the Oracle database tables automatically or manually.
- Changes to either the Oracle database tables or the cache group can be tracked automatically.

When rows in a cache group are updated by applications, the corresponding rows in the Oracle database tables can be updated synchronously as part of the same transaction or asynchronously immediately afterward depending on the type of cache group. The asynchronous configuration produces significantly higher throughput and much faster application response times.

Changes that originate in the Oracle database tables are refreshed into the cache by the *cache agent*.

See Caching in TimesTen.

Replication

TimesTen Classic *replication* enables you to achieve near-continuous availability or workload distribution by sending updates between two or more hosts.

A master host is configured to send updates and a subscriber host is configured to receive them. A host can be both a master and a subscriber in a bidirectional replication scheme. Time-based conflict detection and resolution are used to establish precedence in case the same data is updated in multiple locations at the same time.

TimesTen recommends the *active standby pair* replication scheme configuration for highest availability. It is the only replication configuration that you can use for replicating cache groups. An active standby pair includes an active database, a standby database, and optional read-only subscriber databases.

When replication is configured, a *replication agent* is started for each database. Each replication agent can send updates to one or more subscribers and to receive updates from one or more masters. Each of these connections is implemented as a separate thread running inside the replication agent process. Replication agents communicate through TCP/IP stream sockets.

For maximum performance, the replication agent detects updates to a database by monitoring the existing transaction log. It sends updates to the subscribers in batches, if possible. Only committed transactions are replicated. On the subscriber host, the replication agent updates the database through an efficient internal interface that avoids the overhead of the SQL layer.

See Data Replication Within TimesTen Classic for more information about replication configurations.

4
Concurrent Operations

When a database is accessed by multiple applications, there must be a way to coordinate concurrent changes to data with read operations of the same data in the database. TimesTen uses transaction isolation and locks to coordinate concurrent access to data.

This chapter includes the following topics:

- Transaction Isolation
- Locking Levels

For more information about locks and transaction isolation, see Transaction Management in *Oracle TimesTen In-Memory Database Operations Guide*.

Transaction Isolation

Transaction isolation provides an application with the appearance that the system processes one transaction at a time, even though there are concurrent connections to the database. Applications can use the `Isolation` general connection attribute to set the isolation level for a connection.

Concurrent connections can use different isolation levels.

Isolation level and concurrency are inversely related. A lower isolation level enables greater concurrency, but with greater risk of data inconsistencies. A higher isolation level provides a higher degree of data consistency, but at the expense of concurrency.

TimesTen supports two isolation levels:

- Read Committed Isolation
- Serializable Isolation

Read Committed Isolation

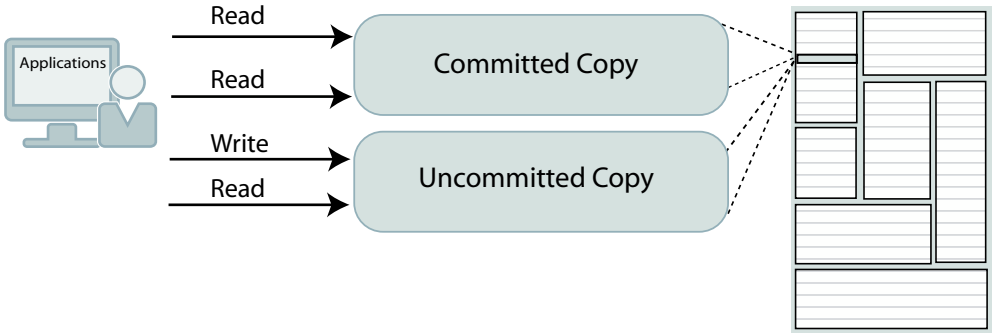
Read committed isolation provides increased concurrency because readers do not block writers and writers do not block readers.

When an application uses read committed isolation, readers use a separate copy of the data from writers, so read locks are not needed. Read committed isolation is non-blocking for queries. Under read committed isolation, writers block only other writers and readers using serializable isolation; writers do not block readers using read committed isolation. Read committed isolation is the default isolation level.

TimesTen uses *versioning* to implement read committed isolation. TimesTen update operations create new copies of the rows they update to allow nonserializable read operations of those rows to proceed without waiting.

Figure 4-1 shows that some applications read a committed copy of the data while another application writes and reads on an uncommitted copy.

Figure 4-1 Read Committed Isolation



This isolation level is useful for applications that have long-running scans that may conflict with other operations needing access to a scanned row. However, the disadvantage when using this isolation level is that non-repeatable read operations are possible within a transaction or even a single statement (for example, the inner loop of a nested join).

When using this isolation level, DDL statements that operate on a table can block readers and writers of that table. For example, an application cannot read a row from a table if another application has an uncommitted `DROP TABLE`, `CREATE INDEX`, or `ALTER TABLE` operation on that table. In addition, blocking checkpoints block both readers and writers.

Read committed isolation does acquire read locks as needed during materialized view maintenance to ensure that views are consistent with their detail tables. These locks are not held until the end of the transaction but are instead released when materialized view maintenance has been completed.

Serializable Isolation

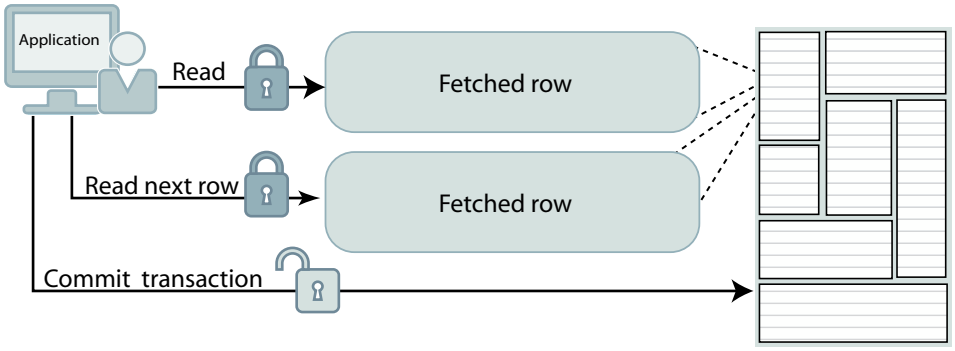
When an application uses serializable isolation, locks are acquired within a transaction and are held until the transaction commits or rolls back for both read and write operations.

As a result, a row that has been read by one transaction cannot be updated or deleted by any other transaction until the first transaction completes. Similarly, a row that has been inserted, updated, or deleted by a transaction cannot be accessed in any way by any other transaction until the first transaction completes.

This level of isolation provides for repeatable read operations and increased isolation within a transaction at the expense of decreased concurrency. Transactions use serializable isolation when database-level locking is chosen.

Figure 4-2 shows that locks are held until the transaction is committed.

Figure 4-2 Serializable Isolation



Serializable isolation level is useful for transactions that require the strongest level of isolation. Concurrent applications that must modify the data that is read by another transaction may encounter lock timeouts because read locks are held until the transaction commits.

Locking Levels

Locks are used to serialize access to resources to prevent one user from changing a resource that is being read or changed by another user.

TimesTen automatically performs locking for all database accesses.

- A shared lock enables the associated resource to be shared, depending on the operations involved (that is, you cannot alter or drop a row, table, or view if it is being shared). Several transactions can acquire shared locks on the same resource.
- An exclusive lock ensures that there is no more than one active transaction in the database at any given time. This lock prevents the resource from being shared and is obtained to modify data. The first transaction to lock a resource exclusively is the only transaction that can alter the resource until the exclusive lock is released when the transaction completes.

Serializable transactions acquire shared locks on the items they read and exclusive locks on the items they write. These locks are held until the transaction commits or rolls back. Read-committed transactions acquire exclusive locks on the items they write and hold these locks until the transactions are committed. Read-committed transactions do not acquire locks on the items they read. Committing or rolling back a transaction closes all cursors and releases all locks held by the transaction.

TimesTen performs deadlock detection to report and eliminate deadlock situations. If an application is denied a lock because of a deadlock error, it should roll back the entire transaction and retry it.

Applications can select from three lock levels:

- Row-Level Locking
- Table-Level Locking
- Database-Level Locking

Row-Level Locking

Row-level locking locks only the rows that are accessed by a transaction. It provides the best concurrency by enabling concurrent transactions to access rows in the same table.

Row-level locking is preferable when there are many concurrent transactions, each operating on different rows of the same tables.

Applications can use the `LockLevel` general connection attribute, the `ttLockLevel` built-in procedure or the `ttOptSetFlag` built-in procedure to manage row-level locking.

See ttLockLevel and ttOptSetFlag in the *Oracle TimesTen In-Memory Database Reference*.

Table-Level Locking

Table-level locking locks a table when it is accessed by a transaction. It is useful when a statement accesses most of the rows in a table. Applications can call the `ttOptSetFlag` built-in procedure to request that the optimizer use table locks. The optimizer determines when a table lock should be used.

Table locks can reduce throughput, so they should be used only when a substantial portion of the table must be locked or when high concurrency is not needed. For example, tables can be locked for operations such as bulk updates. In read-committed isolation, TimesTen does not use table-level locking for read operations unless it is explicitly requested by the application.

See ttOptSetFlag in the *Oracle TimesTen In-Memory Database Reference*.

Database-Level Locking

Locking at the database level locks an entire database when it is accessed by a transaction. All database-level locks are exclusive. Use the `LockLevel` general connection attribute or the `ttLockLevel` built-in procedure to implement database-level locking.

A transaction that requires a database-level lock cannot start until there are no active transactions on the database. After a transaction has obtained a database-level lock, all other transactions are blocked until the transaction commits or rolls back.

Database-level locking restricts concurrency more than table-level locking and is useful only for initialization operations such as bulk loading, when no concurrency is necessary. Database-level locking has better response time than row-level or table-level locking at the cost of diminished concurrency and diminished throughput.

Different transactions can coexist with different levels of locking, but the presence of even one transaction that uses database-level locking leads to reduced concurrency.

See ttLockLevel in the *Oracle TimesTen In-Memory Database Reference*.

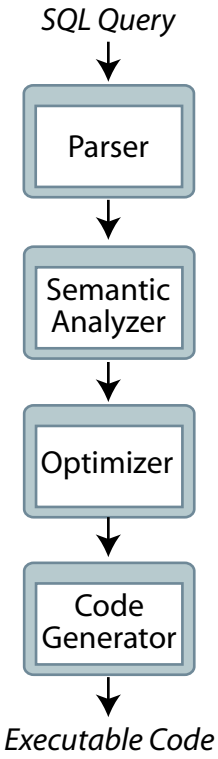
5

Query Optimization

TimesTen has a cost-based query optimizer that ensures efficient data access by automatically determining the most efficient way to run a given query by considering possible query plans. Optimization is performed in the third stage of the compilation process.

The stages of compilation are shown in Figure 5-1.

Figure 5-1 Compilation Stages



TimesTen invokes the optimizer for SQL statements when more than one execution plan is possible. The optimizer chooses what it thinks is the optimum plan. This plan persists until the statement is either invalidated or dropped by the application.

The optimizer determines the cost of a plan based on:

- Table and column statistics
- Metadata information (such as referential integrity, primary key)
- The presence or absence of indexes. Index choices, including the creation of temporary indexes.
- The volume of data
- The number of unique values

- The selectivity of predicates
- Scan methods (full table scan, rowid lookup, range index scan, hash index lookup)
- Join algorithm choice (nested loop join, nested loop join with indexes, or merge join)

This chapter includes the following topics:

See The TimesTen Query Optimizer in *Oracle TimesTen In-Memory Database Operations Guide*.

Optimization Time and Memory Usage

The optimizer is designed to generate the best possible plan within reasonable time and memory constraints.

Because of the size of the search space (which grows exponentially with the number of tables in a join), the optimizer cannot always choose an optimal plan for every query. Instead, the goal of the optimizer is to choose a good plan from among a set of plans generated by using strategies for finding the most promising areas within the search-space of plans. Since query optimization is relatively expensive relative to execution, the optimizer is designed to give precedence to runtime over optimization time.

The plans generated by the optimizer emphasize performance over memory usage. The optimizer may designate the use of significant amounts of temporary memory space in order to speed up runtime. In memory-constrained environments, applications can use the optimizer hints described in Optimizer Hints to disable the use of temporary indexes and tables in order to create plans that trade maximum performance for reduced memory usage.

Statistics

When determining the execution path for a query, the optimizer examines statistics about the data referenced by the query.

The statistics can include the number of rows in the tables, the minimum and maximum values and the number of unique values in interval statistics of columns used in predicates, the existence of primary keys and unique constraints within a table, and the size and configuration of any existing indexes.

Table-level and column-level statistics are stored in the `SYS.TBL_STATS` and `SYS.COL_STATS` tables. These tables are populated when an application calls the `ttOptUpdateStats` or `ttOptEstimateStats` built-in procedures, or uses the `ttIsql statsupdate` or `statsestimate` commands.

The optimizer uses the statistics for each table to calculate the *selectivity* of predicates, such as `t1.a=4`, or a combination of predicates, such as `t1.a=4 AND t1.b<10`. *Selectivity* is an estimate of the number of rows in a table. If a predicate selects a small percentage of rows, it

is said to have *high* selectivity, while a predicate that selects a large percentage of rows has *low* selectivity.

Optimizer Hints

You can apply *hints* to pass instructions to the TimesTen query optimizer. The optimizer considers these hints when choosing the best execution plan for your query.

You can apply hints as follows:

- To apply a hint only for a particular SQL statement, use a statement level optimizer hint.
- To apply a hint for an entire transaction, use a transaction level optimizer hint with the appropriate TimesTen built-in procedure.
- To apply a hint for every SQL statement in the user application, use a connection level optimizer hint with the `OptimizerHint` connection attribute.

The order of precedence for optimizer hints is statement level hints, transaction level hints and then connection level hints.

See Use Optimizer Hints to Modify the Execution Plan in the *Oracle TimesTen In-Memory Database Operations Guide*.

Indexes

The query optimizer uses indexes to speed up the processing of a query. The optimizer uses existing indexes or creates temporary indexes to generate an execution plan.

An index is a map of keys to row locations in a table. Strategic use of indexes is essential to obtain maximum performance from a TimesTen system.

TimesTen uses these types of indexes:

TimesTen uses two types of indexes, each of which can be defined as unique or not unique (the default):

- *Hash index*: Hash indexes are useful for finding rows with an exact match on one or more columns. You create a hash index with the `CREATE HASH INDEX` SQL statement. In general, hash indexes are faster than range indexes for exact match lookups and equi-joins. However, hash indexes cannot be used for lookups involving ranges or the prefix of a key and can require more space than range indexes.
- *Range index*: Range indexes are useful for finding rows with column values within a range specified as an equality or inequality. Range indexes can be created over one or more columns of a table. You create a range index with the `CREATE INDEX` SQL statement.

See Understanding Indexes in *Oracle TimesTen In-Memory Database Operations Guide*. Also, see descriptions for CREATE INDEX in *Oracle TimesTen In-Memory Database SQL Reference*.

The Index Advisor tool can be used to recommend a set of indexes that could improve the performance of a specific SQL workload. See Using the Index Advisor to Recommend Indexes in the *Oracle TimesTen In-Memory Database Operations Guide*.

Scan Methods

The optimizer can select from multiple types of scan methods.

The most common scan methods are:

- Full table scan: A *full table scan* examines every row in a table. Because it is typically the least efficient way to evaluate a query predicate, a full scan is only used when no other method is available.
- Rowid lookup: A *rowid* is an address (a unique ID) of a physical tuple in a table to each row stored in a table. A *rowid lookup* is applicable if, for example, an application has previously selected a rowid and then uses a `WHERE ROWID=` clause to fetch that same row. Rowid lookups are faster than index lookups.

  However, since TimesTen Scaleout may be configured to have multiple copies, then each copy would have a different `ROWID`. Since `ROWID` is the identifier of a specific copy of a row, if that copy is not available, you cannot access the row by `ROWID`. In this case, you should access the row by primary key.

  See Understanding ROWID in Data Distribution in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.
- Range index scan (on either a permanent or temporary index): A *range index scan* uses a range index to access a table. Such a scan is applicable to exact match predicates such as `t1.a=2` or to range predicates such as `t1.a>2` and `t1.a<10` as long as the column used in the predicate has a range index defined over it. If a range index is defined over multiple columns, it can be used for multiple column predicates. For example, the predicates `t1.b=100` and `t1.c>'ABC'` result in a range index scan if a range index is defined over columns `t1.b` and `t1.c`. The index can be used if it is defined over more columns. For example, if a range index is defined over `t1.b`, `t1.c` and `t1.d`, the optimizer uses the index prefix over columns `b` and `c` and returns all the values for column `d` that match the stated predicate over columns `b` and `c`.
- Hash index lookup (on either a permanent or temporary index): A *hash index lookup* uses a hash index to find rows with an exact match on one or more columns. Such lookups are applicable for equality searches over one or more specified columns.

TimesTen performs fast exact matches through hash indexes and rowid lookups. They perform range matches through range indexes. Optimizer hints can be used to allow or disallow the optimizer from considering certain scan methods when choosing a query plan.

Join Methods

The optimizer can select from multiple join methods. When the rows from two tables are joined, one table is designated the *outer table* and the other the *inner table*. The optimizer decides which of the tables should be the outer table and which should be the inner table. During a join, the optimizer scans the rows in the outer and inner tables to locate the rows that match the join condition.

The optimizer analyzes the statistics for each table and, for example, might identify the smallest table or the table with the best selectivity for the query as outer table. If indexes exist for one or more of the tables to be joined, the optimizer takes them into account when selecting the outer and inner tables.

If more than two tables are to be joined, the optimizer analyzes the various combinations of joins on table pairs to determine which pair to join first, which table to join with the result of the join, and so on for the optimum sequence of joins.

The cost of a join is largely influenced by the method in which the inner and outer tables are accessed to locate the rows that match the join condition. The optimizer selects from two join methods when determining the query optimizer plan:

Nested Loop Join

In a nested loop join with no indexes, a row in the outer table is selected one at a time and matched against every row in the inner table. All the rows in the inner table are scanned as many times as the number of rows in the outer table.

If the inner table has an index on the join column, that index is used to select the rows that meet the join condition. The rows from each table that satisfy the join condition are returned. Indexes may be created on the fly for inner tables in nested loops, and the results from inner scans may be materialized before the join.

Figure 5-2 shows an example of a nested loop join. The join condition is:

```
WHERE t1.a=t2.a
```

For this example, the optimizer has decided that `t1` is the outer table and `t2` is the inner table. Values in column `a` in table `t1` that match values in column `a` in table `t2` are 1 and 7. The join results concatenate the rows from `t1` and `t2`. For example, the first join result is the following row:

7 50 43.54 21 13.69

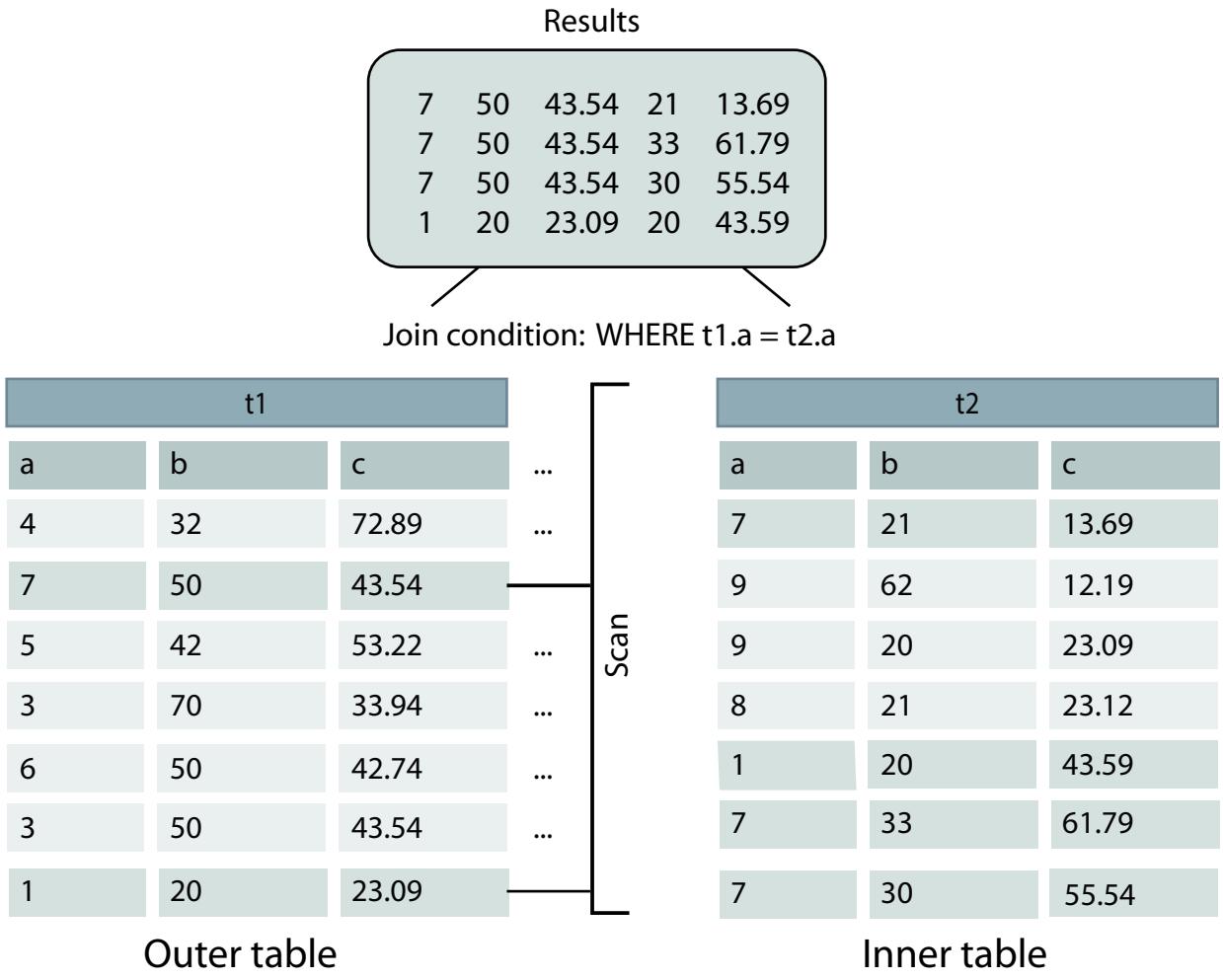
It concatenates a row from `t1`:

7 50 43.54

with the first row from `t2` in which the values in column `a` match:

7 21 13.69

Figure 5-2 Nested Loop Join



Merge Join

A merge join is used only when the join columns are sorted by range indexes. In a merge join, a cursor advances through each index one row at a time. Because the rows are already sorted on the join columns in each index, a simple formula is applied to efficiently advance the cursors through each row in a single scan. The formula looks something like:

- If Inner.JoinColumn < Outer.JoinColumn, then advance inner cursor
- If Inner.JoinColumn = Outer.JoinColumn, then read match
- If Inner.JoinColumn > Outer.JoinColumn, then advance outer cursor

Unlike a nested loop join, there is no need to scan the entire inner table for each row in the outer table. A merge join can be used when range indexes have been created for the tables before preparing the query. If no range indexes exist for the tables being joined before preparing the query, the optimizer may in some situations create temporary range indexes in order to use a merge join.

Figure 5-3 shows an example of a merge join. The join condition is:

```
WHERE t1.a=t2.a
```

`x1` is the index on table `t1`, sorting on column `a`. `x2` is the index on table `t2`, sorting on column `a`. The merge join results concatenate the rows in `x1` with rows in `x2` in which the values in column `a` match. For example, the first merge join result is:

1 20 23.09 20 43.59

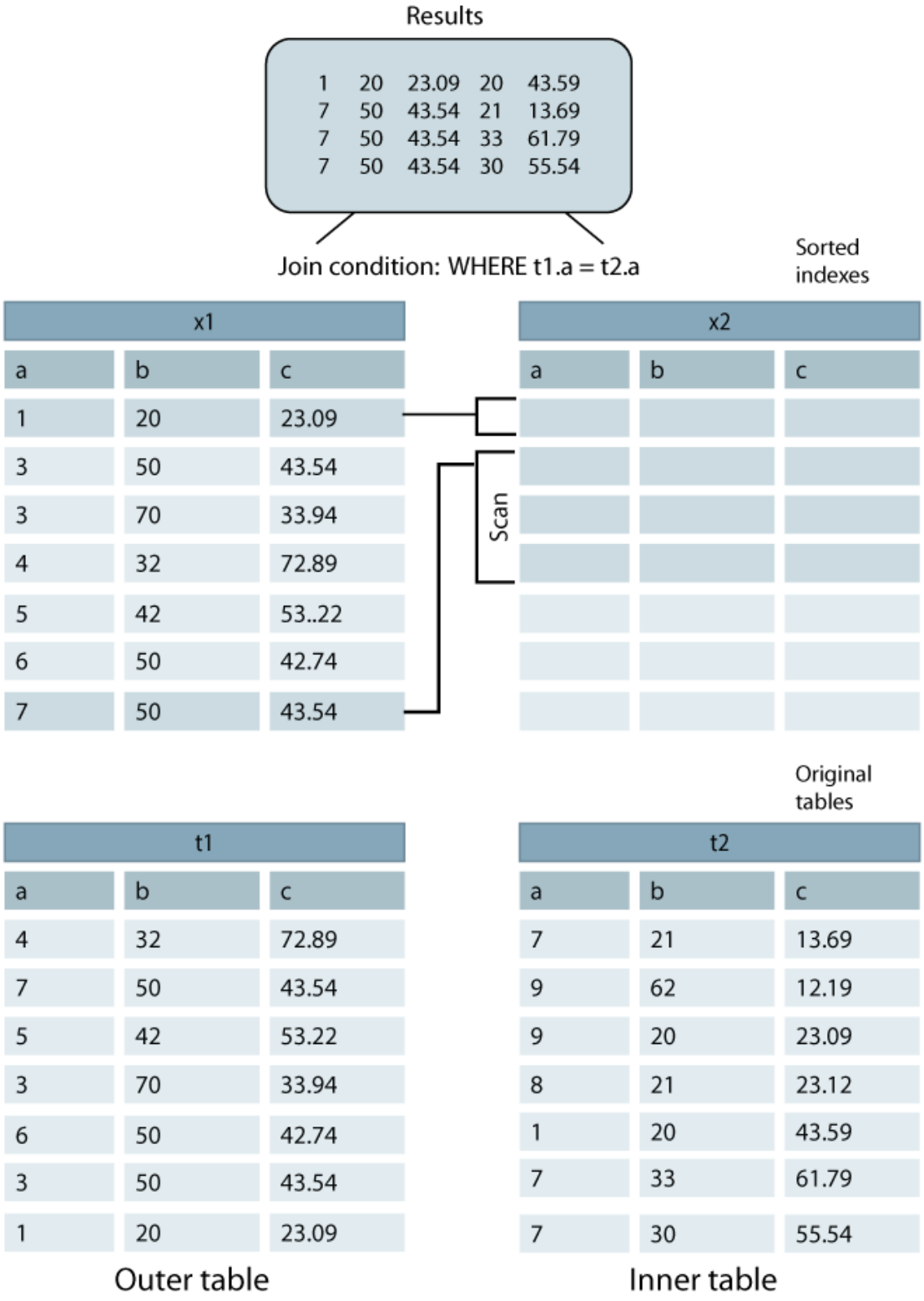
It concatenates a row in `x1`:

1 20 23.09

with the first row in `x2` in which the values in column `a` match:

1 20 43.59

Figure 5-3 Merge Join



Optimizer Plan

Like the optimizer in most other relational databases, the query optimizer stores the details on how to most efficiently perform SQL operations in a query execution plan, which can be examined and customized by application developers and administrators.

The execution plan data is stored in the TimesTen `SYS.PLAN` table and includes information about which tables are to be accessed and in what order, which tables are to be joined, and which indexes are to be used. You can use either the `ttSqlCmdQueryPlan` built-in procedure or the `ttIsql explain` command to display the query plans for recently processed SQL statements. Users can direct the query optimizer to enable or disable the creation of an execution plan in the `SYS.PLAN` table with the generate plan optimizer hint. (For transaction level hints, use the `GenPlan` optimizer flag in the `ttOptSetFlag` built-in procedure; for statement level hints, use the `TT_GenPlan` hint in the SQL statement.) See The TimesTen Query Optimizer in the *Oracle TimesTen In-Memory Database Operations Guide* for more information.

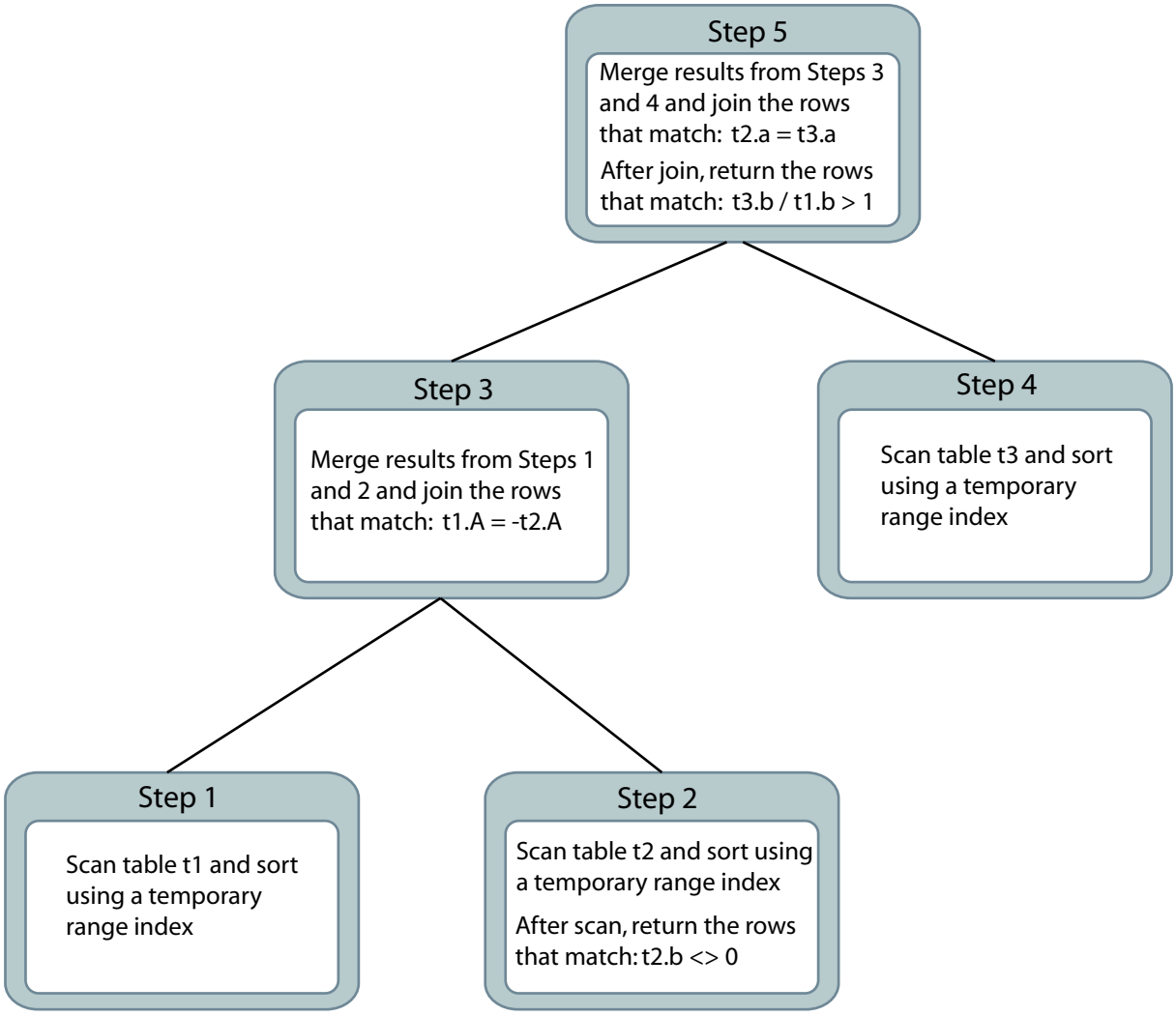
The execution plan designates a separate step for each database operation to be performed to run the query. The steps in the plan are organized into levels that designate which steps must be completed to generate the results required by the step or steps at the next level.

Consider this query:

```
SELECT COUNT(*)
  FROM t1, t2, t3
    WHERE t3.b/t1.b > 1
      AND t2.b <> 0
      AND t1.a = -t2.a
      AND t2.a = t3.a;
```

In this example, the optimizer breaks down the query into its individual operations and generates a 5-step execution plan to be performed at three levels, as shown in Figure 5-4.

Figure 5-4 Example Execution Plan



6

Data Availability and Integrity

TimesTen ensures the availability, durability, and integrity of data through transaction logging, checkpointing and replication.

- Transaction Logging
- Checkpointing
- Data Replication Within TimesTen Classic

Transaction Logging

The transaction log is used for multiple purposes.

- Redo transactions if a system failure occurs
- Undo transactions that are rolled back
- Replicate changes to other TimesTen databases
- When using cache, replicate changes to an Oracle database
- For TimesTen Classic, enable applications to monitor changes to tables through the XLA interface

The transaction log is stored in files on the file system. The end of the transaction log resides in an in-memory buffer.

> **Note:**
>
> For more information about logging and checkpointing, see Transaction Management in the *Oracle TimesTen In-Memory Database Operations Guide*.

The following sections describe the processes of transaction logging:

- Writing the Transaction Log Buffer to the File System
- When Are Transaction Log Files Deleted?
- TimesTen Commits

Writing the Transaction Log Buffer to the File System

TimesTen writes the contents of the in-memory transaction log buffer to transaction log files on the file system at every durable commit, at every checkpoint, and at other times defined by the implementation.

Applications that cannot tolerate the loss of any committed transactions if a failure occurs should request a durable commit for every transaction that is not read-only by setting the appropriate durability connection attribute to 1.

Applications that can tolerate the loss of some recently committed transactions can significantly improve their performance by committing some or all of their transactions non-durably. To do so, set the appropriate durability connection attribute to 0 and request explicit durable commits either at regular time intervals or at specific points in their application logic.

For setting the correct durability connection attribute and how to request explicit durable commits for TimesTen Classic, see Durability Options in the *Oracle TimesTen In-Memory Database Operations Guide*. For setting the correct durability connection attribute and how to request explicit durable commits for TimesTen Scaleout, see Durability Settings in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

When Are Transaction Log Files Deleted?

Transaction log files are kept until TimesTen declares them to be purgeable. When a transaction log file is purgeable, the next checkpoint operation deletes that transaction log file.

A transaction log file cannot be purged until all of the following actions have been completed:

- All transactions writing log records to the transaction log file (or a previous transaction log file) have committed or rolled back.
- All changes recorded in the transaction log file have been written to the checkpoint files.
- When using TimesTen Classic replication, all changes recorded in the transaction log file have been replicated.
- When using cache, all changes recorded in the transaction log file have been propagated to the Oracle database if cache has been configured for that behavior.
- When XLA is used in TimesTen Classic, all changes recorded in transaction log files have been reported to the XLA applications.

See Checkpointing.

TimesTen Commits

ODBC provides an autocommit mode that forces a commit after each statement.

By default, autocommit is enabled so that an implicit commit is issued immediately after a statement runs successfully. TimesTen recommends that you turn autocommit off so that commits are intentional.

TimesTen issues an implicit commit before and after any data definition language (DDL) statement.

Checkpointing

Checkpoints are used to keep a snapshot of the database. If a system failure occurs, TimesTen can use a checkpoint file and transaction log files to restore a database to its last transactionally consistent state.

Only the data that has changed since the last checkpoint operation is written to the checkpoint file. The checkpoint operation scans the database for blocks that have changed since the last checkpoint. It then updates the checkpoint file with the changes and removes any transaction log files that are no longer needed (those that have been declared as purgeable). See When Are Transaction Log Files Deleted?.

TimesTen provides two kinds of checkpoints:

- Non-Blocking Checkpoints

- Blocking Checkpoints
- Recovery From the Transaction Log and Checkpoint Files

TimesTen creates non-blocking checkpoints automatically.

For more information about checkpointing, see Checkpoint operations in the *Oracle TimesTen In-Memory Database Operations Guide*.

Non-Blocking Checkpoints

TimesTen initiates non-blocking checkpoints in the background automatically. Non-blocking checkpoints are also known as *fuzzy* checkpoints.

The frequency of these checkpoints can be adjusted by the application. Non-blocking checkpoints do not require any locks on the database, so multiple applications can asynchronously commit or roll back transactions on the same database while the checkpoint operation is in progress. See Setting and Managing Checkpoints in the *Oracle TimesTen In-Memory Database Operations Guide*.

Blocking Checkpoints

When using TimesTen Classic, an application can call the `ttCkptBlocking` built-in procedure to initiate a blocking checkpoint in order to construct a transaction-consistent checkpoint.

Blocking checkpoints acquire an exclusive database lock. While a blocking checkpoint operation is in progress, any other new transactions are put in a queue behind the checkpointing transaction. Thus, a long running transaction may cause other transactions to be held up. A long-running transaction could prevent a blocking checkpoint from acquiring the exclusive database lock, which could cause the checkpoint and all subsequent transactions to wait until the long-running transaction commits or rolls back (or the checkpoint request is canceled). No transaction log is needed to recover from a blocking checkpoint since the checkpoint record contains the information needed to recover.

See Setting and Managing Checkpoints in the *Oracle TimesTen In-Memory Database Operations Guide*.

Recovery From the Transaction Log and Checkpoint Files

During recovery, the latest checkpoint file is read into memory. All transactions that have been committed since the last checkpoint and whose log records are on the file system are rolled forward from the appropriate transaction log files.

Note that the transactions on the file system include all transactions that were committed durably as well as all transactions whose log records aged out of the in-memory transaction log buffer. Uncommitted or rolled-back transactions are not recovered.

- When using TimesTen Scaleout, there is a process to facilitate automatic recovery of the data from the checkpoint and transaction log files. See Recovering From Failure in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.
- When using TimesTen Classic, if a database becomes invalid or corrupted by a system or process failure, every connection to the database is invalidated. When an application reconnects to a failed database, the subdaemon allocates a new memory region for the database and recovers its data from the checkpoint and transaction log files.

For applications that require uninterrupted access to TimesTen Classic data in the event of failures, see Data Replication Within TimesTen Classic.

Data Replication Within TimesTen Classic

The fundamental motivation behind data replication in TimesTen Classic is to make data highly available to applications with minimal performance impact. In addition to its role in failure recovery, replication is also useful for distributing application workloads across multiple databases for maximum performance and for facilitating online upgrades and maintenance.

Replication is the process of copying data from a *master* database to a *subscriber* database. Replication at each master and subscriber database is controlled by *replication agents* that communicate through TCP/IP stream sockets. The replication agent on the master database reads the records from the transaction log for the master database. It forwards changes to replicated elements to the replication agent on the subscriber database. The replication agent on the subscriber then applies the updates to its database. If the subscriber agent is not running when the updates are forwarded by the master, the master retains the updates in its transaction log until they can be applied at the subscriber.

You can increase replication throughput by configuring parallel replication at database creation time. You configure the number of threads for applying updates to subscribers. The updates are transmitted in commit order. See Configuring Automatic Parallel Replication in the Oracle TimesTen In-Memory Database Replication Guide.

TimesTen recommends the active standby pair configuration for highest availability. It is the only replication configuration that you can use for replicating cache groups.

> **Note:**
>
> For more information about replication, see Overview of TimesTen Replication in the *Oracle TimesTen In-Memory Database Replication Guide*.

The rest of this section includes the following topics:

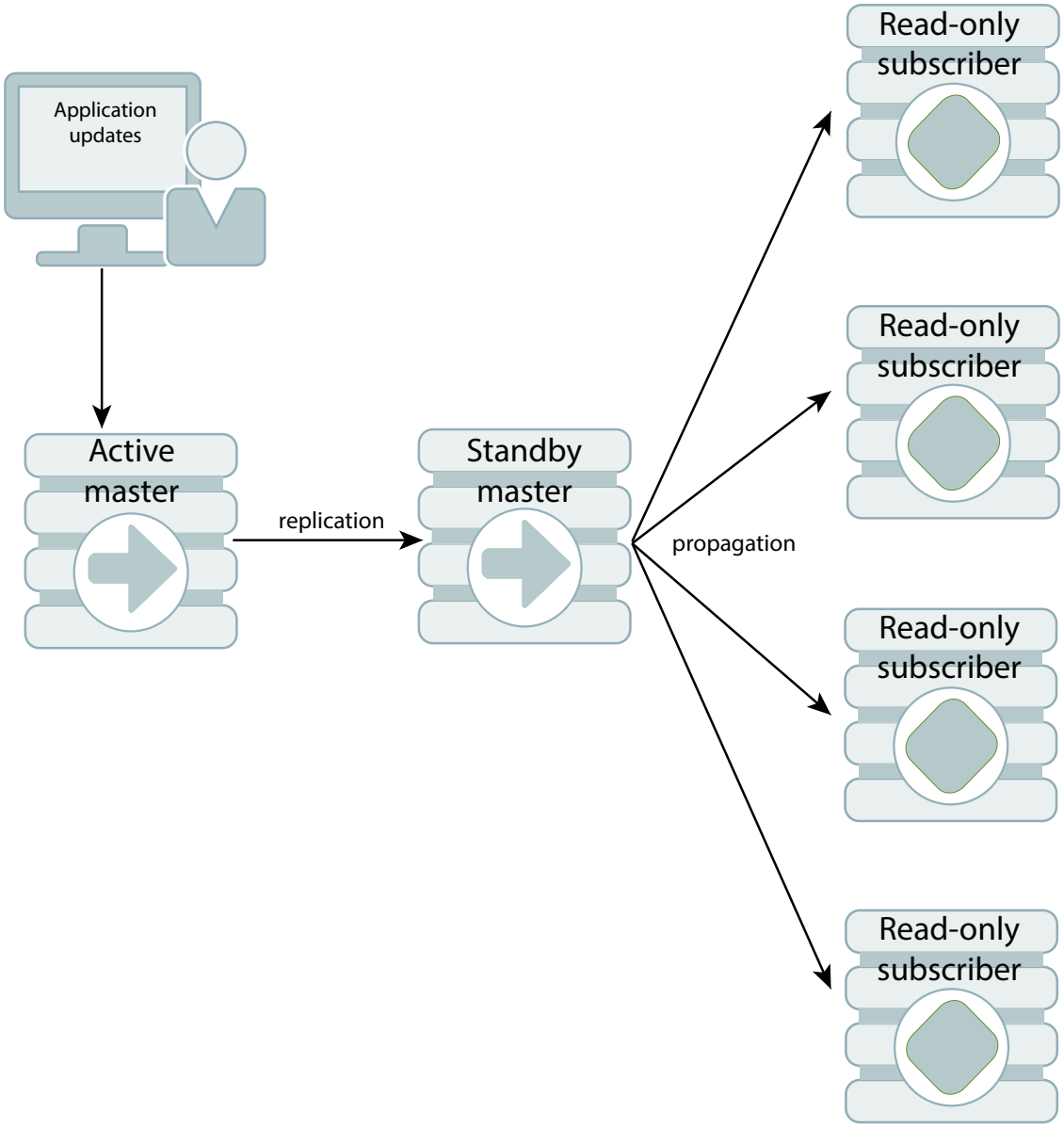
- Active Standby Pair
- Classic Replication Configurations
- Asynchronous and Return Service Replication
- Replication Failover and Recovery
- Automatic Client Failover for Active Standby Pair Replication

Active Standby Pair

An active standby pair includes an active database, a standby database, optional read-only subscriber databases, and the tables and cache groups that comprise the databases.

Figure 6-1 shows an active standby pair.

Figure 6-1 Active Standby Pair



In an active standby pair, two databases are defined as masters. One is an active database, and the other is a standby database. The active database is updated directly. The standby database cannot be updated directly. It receives the updates from the active database and propagates the changes to read-only subscribers. This arrangement ensures that the standby database is always ahead of the read-only subscribers and enables rapid failover to the standby database if the active database fails.

Only one of the master databases can function as an active database at a specific time. If the active database fails, the role of the standby database must be changed to active before recovering the failed database as a standby database. The replication agent must be started on the new standby database.

If the standby database fails, the active database replicates changes directly to the read-only subscribers. After the standby database has recovered, it contacts the active database to receive any updates that have been sent to the read-only subscribers while the standby was

down or was recovering. When the active and the standby databases have been synchronized, then the standby resumes propagating changes to the subscribers.

Active standby replication can be used with cache to achieve cross-tier high availability. Active standby replication is available for both read-only and asynchronous writethrough cache groups. When used with read-only cache groups, updates are sent from the Oracle database to the active database. Thus, the Oracle database plays the role of the application in this configuration. When used with asynchronous writethrough cache groups, the standby database propagates updates that it receives from the active database to the Oracle database. In this scenario, the Oracle database plays the role of one of the read-only subscribers.

An active standby pair that replicates one of these types of cache groups can perform failover and recovery automatically with minimal chance of data loss. See Replicating Cache Groups Within Active Standby Pairs in *Oracle TimesTen In-Memory Database Replication Guide*.

Classic Replication Configurations

TimesTen replication architecture is flexible enough to achieve balance between performance and availability.

In general, classic replication can be configured to be:

- Unidirectional Replication: Unidirectional from a master to one or more subscribers.
- Bidirectional Replication: Bidirectional between two or more databases that serve as both master and subscriber.

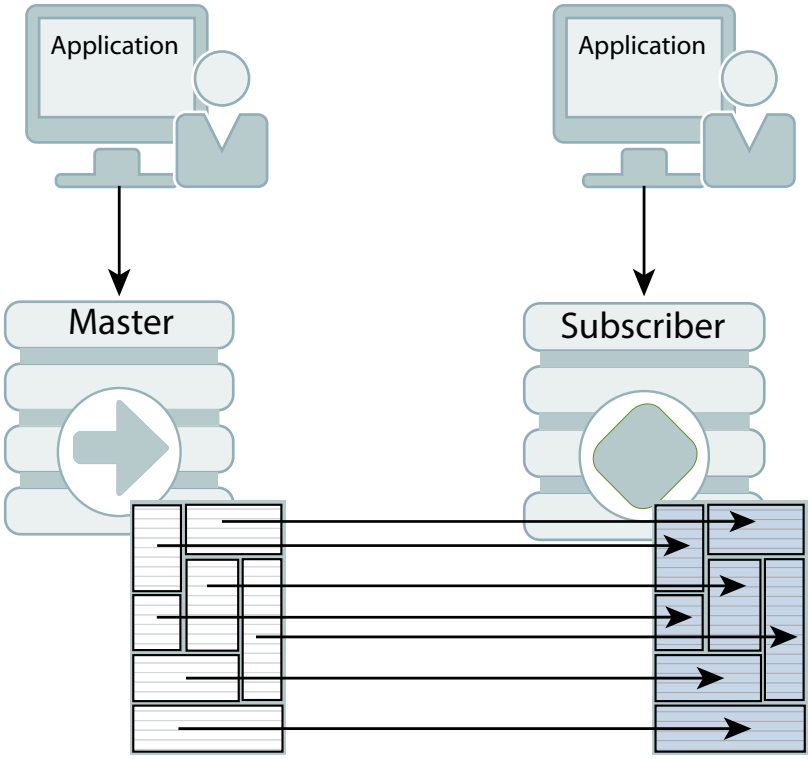
Unidirectional Replication

In a uidirectional replication scheme, the application is configured on both hosts so that the subscriber is ready to take over if the master host fails.

Figure 6-2 shows a *unidirectional* replication scheme.

While the master is up, updates from the application to the master database are replicated to the subscriber database. The application on the subscriber host does not run any updates against the subscriber database, but may read from that database. If the master fails, the application on the subscriber host takes over the update function and starts updating the subscriber database.

Figure 6-2 Unidirectional Replication Scheme



Replication can also be used to copy updates from a master database to many subscriber databases. Figure 6-3 shows a replication scheme with multiple subscribers.

Figure 6-3 Unidirectional Replication to Multiple Subscribers

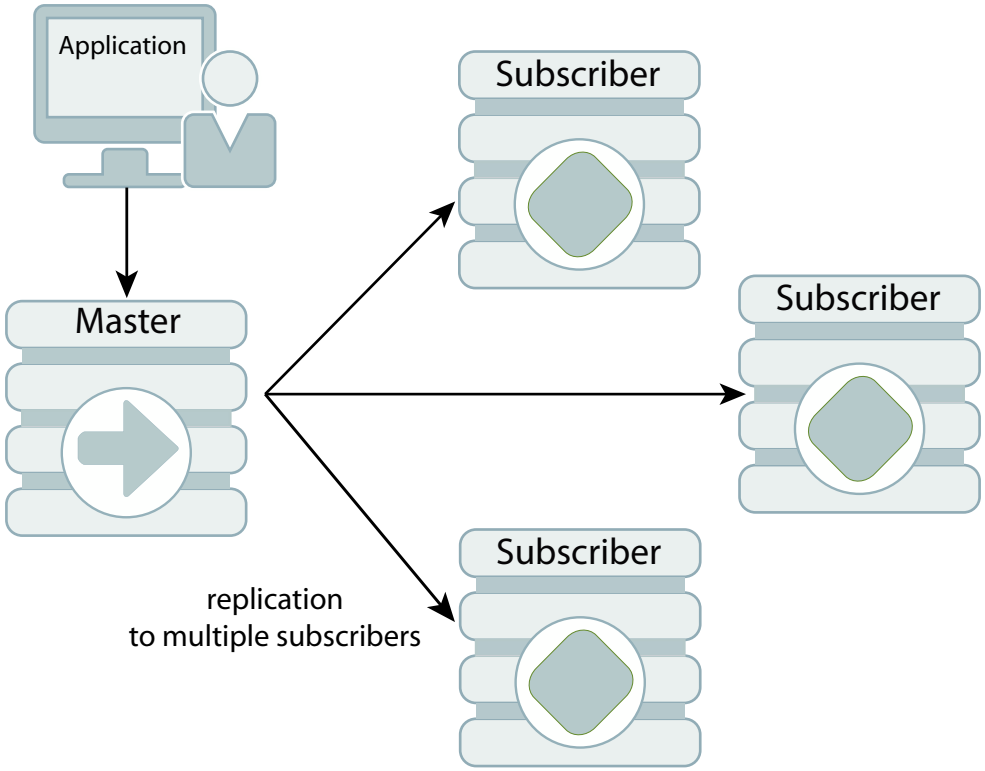
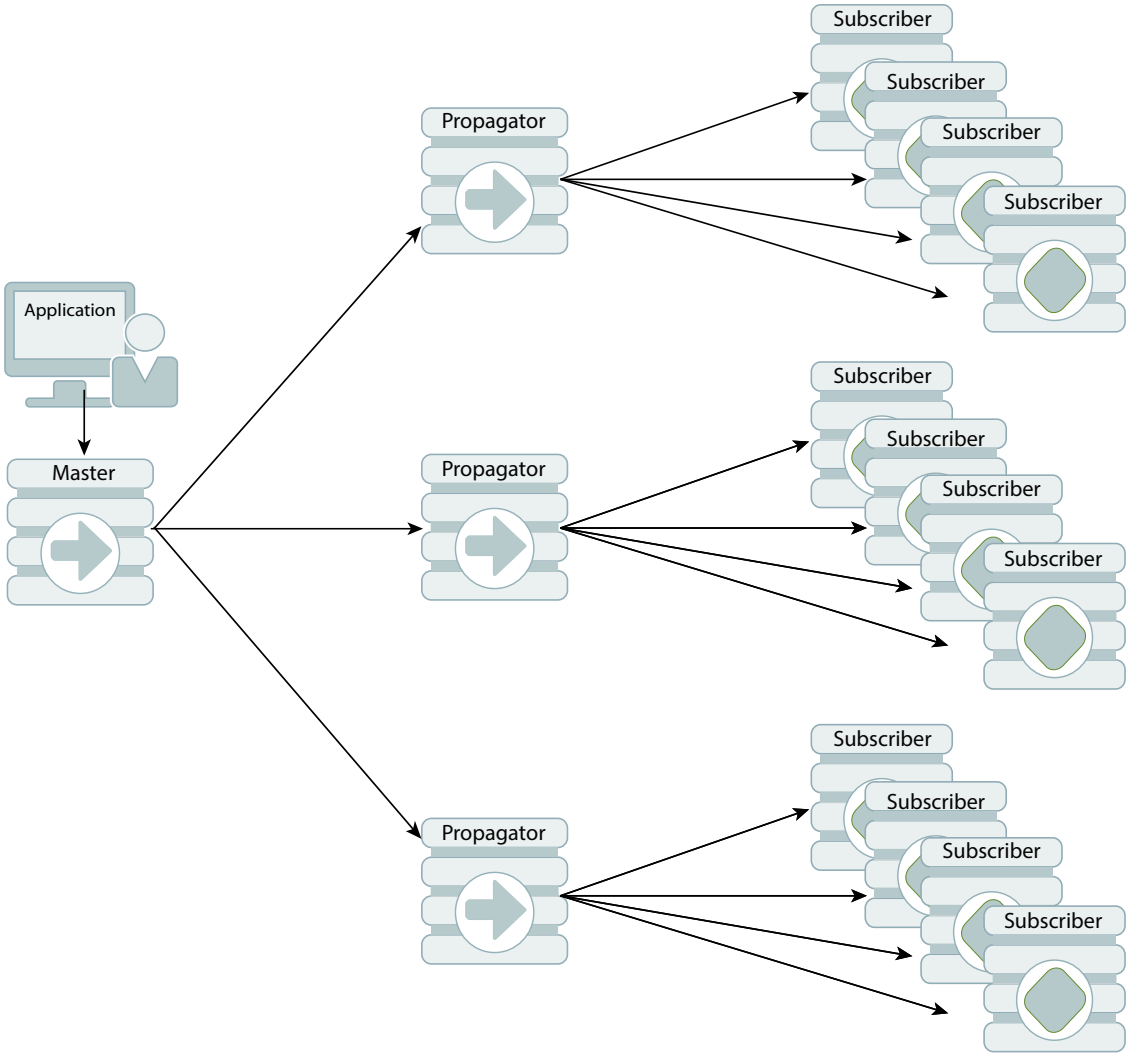


Figure 6-4 shows a *propagation* configuration. One master copies updates to three subscriber nodes, which act as propagator nodes to forward those same updates to additional subscribers.

Figure 6-4 Propagation Configuration



Bidirectional Replication

Bidirectional replication schemes are used for load balancing. The workload can be split between two bidirectionally replicated databases.

There are two basic types of load-balancing configurations:

- *Split workload* where each database bidirectionally replicates a portion of its data to the other database. Figure 6-5 shows a split workload configuration.
- *Distributed workload* where user access is distributed across duplicate application/database combinations that replicate updates to each other. In a distributed workload configuration, the application has the responsibility to divide the work between the two systems so that replication collisions do not occur. If collisions do occur, TimesTen has a timestamp-based collision detection and resolution capability. Figure 6-6 shows a distributed workload configuration.

Figure 6-5 Split Workload Replication

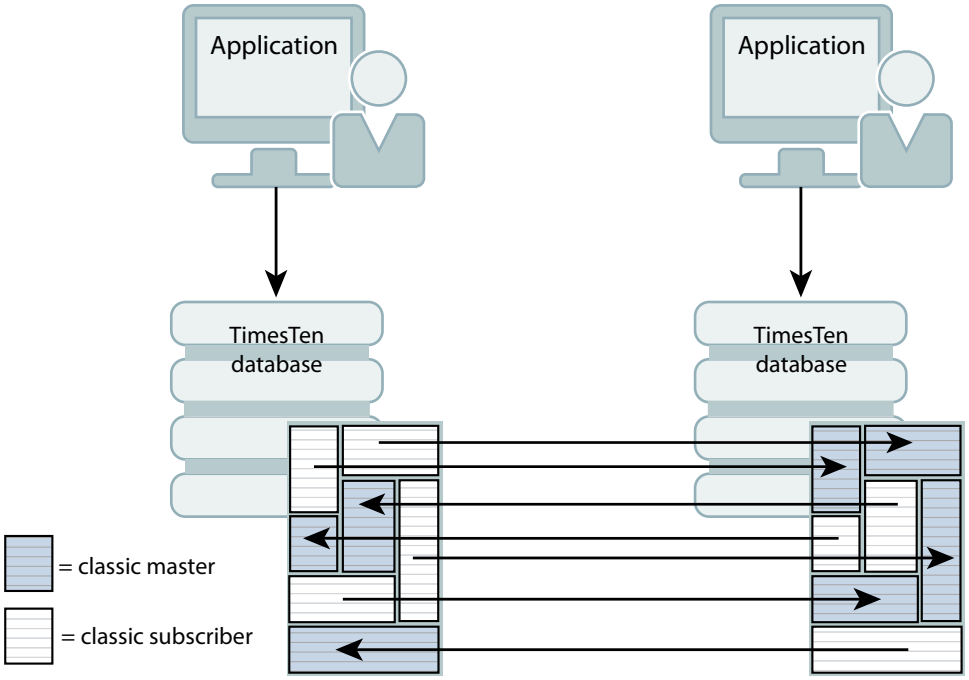
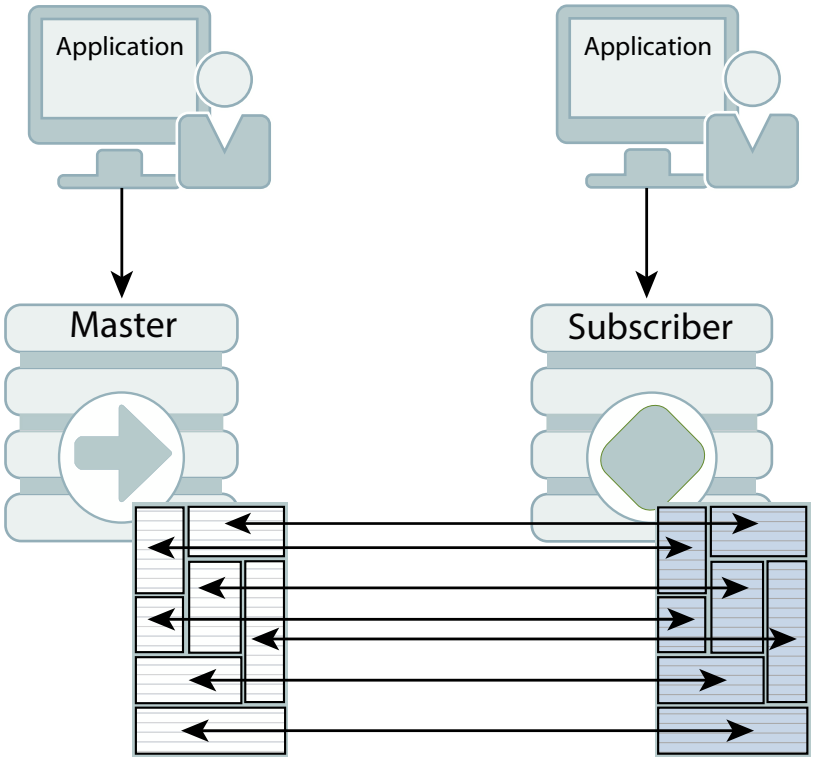


Figure 6-6 Distributed Workload Replication



Asynchronous and Return Service Replication

TimesTen replication is asynchronous by default. When using asynchronous replication, an application updates the master database and continues working without waiting for the updates to be received by the subscribers.

The master and subscriber databases have internal mechanisms to confirm that the updates have been successfully received and committed by the subscriber. These mechanisms ensure that updates are applied at a subscriber only once, but they are invisible to the application.

Asynchronous replication provides maximum performance, but the application is completely decoupled from the receipt process of the replicated elements on the subscriber. TimesTen also provides two *return service* options for applications that need higher levels of confidence that the replicated data is consistent between the master and subscriber databases:

- The *return receipt service* synchronizes the application with the replication mechanism by blocking the application until replication confirms that the update has been received by the subscriber replication agent.
- The *return twosafe service* enables fully synchronous replication by blocking the application until replication confirms that the update has been both received *and committed* on the subscriber.

> **Note:**
>
> Do not use the return twosafe service with bidirectional replication. This can cause deadlocks.

Applications that use the return services trade some performance to ensure higher levels of consistency and reduce the risk of transaction loss between the master and subscriber databases. In the event of a master failure, the application has a higher degree of confidence that a transaction committed at the master persists in the subscribing database. Return receipt replication has less performance impact than return twosafe at the expense of potential loss of transactions.

Replication Failover and Recovery

For replication to make data highly available to applications with minimal performance impact, there must be a way to shift applications from the failed database to its backup as seamlessly as possible.

You can use Oracle Clusterware with TimesTen Classic to manage failures automatically in systems with active standby pairs. Other kinds of replication schemes can be managed with custom and third-party cluster managers. They detect failures, redirect users or applications from the failed database to either a standby database or a subscriber, and manage recovery of the failed database. The cluster manager or administrator can use TimesTen-provided utilities and functions to duplicate the existing database and recover the failed database.

Subscriber failures generally have no impact on the applications connected to the master databases and can be recovered without disrupting user service. If a failure occurs on a master database, the cluster manager must redirect the application load to a standby database or a subscriber in order to continue service with no or minimal interruption.

Automatic Client Failover for Active Standby Pair Replication

You can configure automatic client failover for TimesTen Classic databases that have active standby pairs with client/server connections. This enables the client to fail over automatically to the server on which the standby database resides.

See Using Automatic Client Failover in the *Oracle TimesTen In-Memory Database Operations Guide*.

7

Caching in TimesTen

Caching in TimesTen provides the ability to transfer data between an Oracle database and a TimesTen database.

You can cache data from an Oracle database in a TimesTen database by creating cache groups in TimesTen where each cache group maps to a single table in the Oracle database or to a group of tables related by foreign key constraints.

This chapter includes the following topics:

Cache Groups

You can cache data in an Oracle database by creating a cache group in a TimesTen database. A cache group can be created to cache a single Oracle database table or a set of related Oracle database tables.

The cached data from the Oracle database can consist of all the rows and columns or a subset of the rows and columns in the Oracle database tables.

Cache supports the following features:

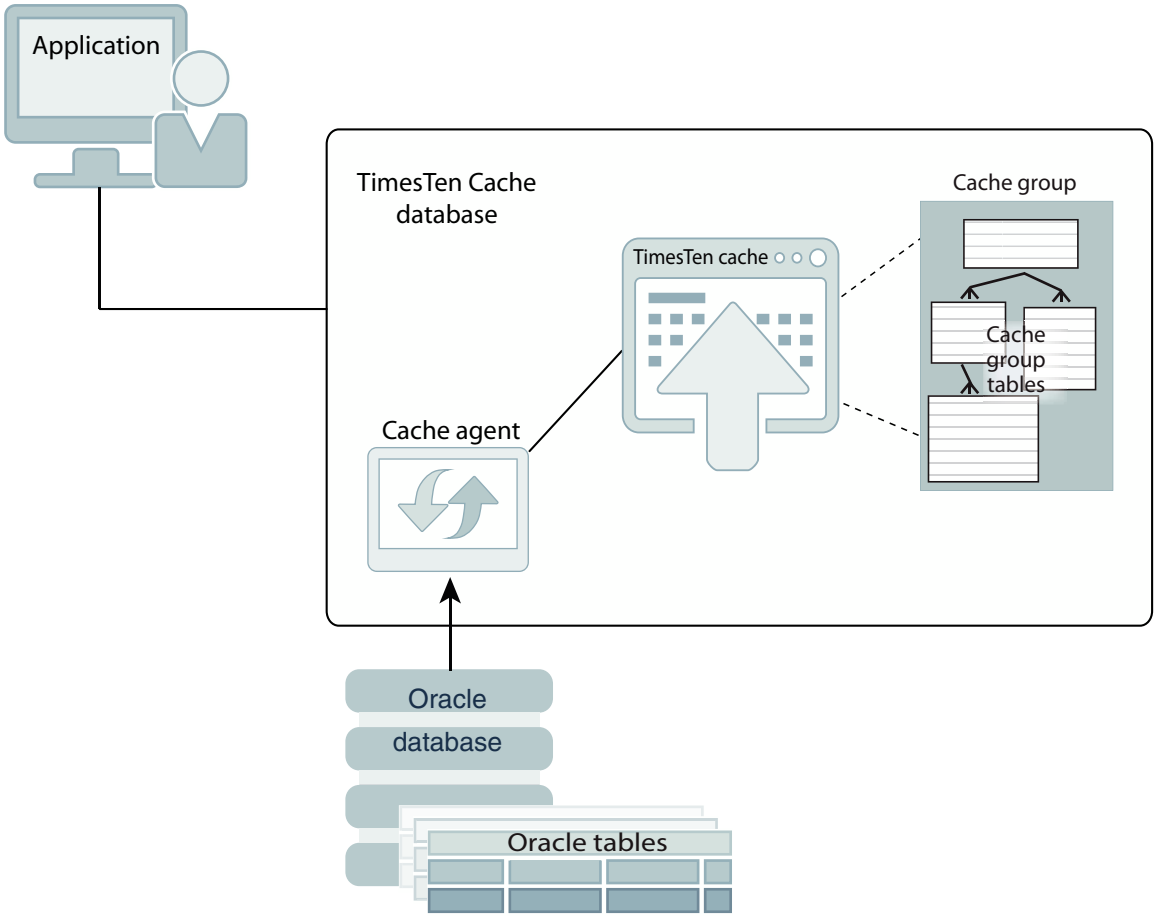
- Applications can both read from and write to cache groups.
- Cache groups can be refreshed (upload the Oracle database data into the cache group) automatically or manually.
- Cache updates can be sent to the Oracle database automatically or manually. The updates can be sent synchronously or asynchronously.

The TimesTen database interacts with the Oracle database to perform all of the synchronous cache group operations, such as creating a cache group and propagating updates between the cache group and the Oracle database. A process called the cache agent performs asynchronous cache operations, such as loading data into the cache group, manually refreshing the data from the Oracle database to the cache group, and automatically refreshing the data from the Oracle database to the cache group.

For full information about cache groups, see Overview of Cache Groups in the *Oracle TimesTen In-Memory Database Cache Guide*.

Figure 7-1 illustrates the cache features and processes in TimesTen.

Figure 7-1 Caching in TimesTen



Each cache group has a *root table* that contains the primary key for the cache group. Rows in the root table may have one-to-many relationships with rows in *child tables*, each of which may have one-to-many relationships with rows in other child tables.

A *cache instance* is the set of rows that are associated by foreign key relationships with a particular row in the root table. Each primary key value in the root table specifies a cache instance. Cache instances form the unit of cache loading and cache aging. No table in the cache group can be a child to more than one parent in the cache group. Each cache record belongs to only one cache instance and has only one parent in its cache group.

The most commonly used cache group types are:

- *Read-only cache group* - A read-only cache group enforces a caching behavior in which committed updates to the Oracle database tables are automatically refreshed to the corresponding cache tables in the TimesTen database.
- *Asynchronous writethrough (AWT) cache group* - An AWT cache group enforces a caching behavior in which committed updates to cache tables in the TimesTen database are automatically propagated to the corresponding the Oracle database tables asynchronously.

Other types of cache groups are:

- *Synchronous writethrough (SWT) cache group* - An SWT cache group enforces a caching behavior in which committed updates to cache tables in the TimesTen database are automatically propagated to the corresponding Oracle database tables synchronously.

- *User managed cache group* - A user managed cache group defines customized caching behavior. For example, individual cache tables in a user managed cache are not constrained to be all of the same type. Some tables may be defined as read-only while others may be defined as updatable.

If you have multiple TimesTen databases, the data in cached tables is not shared among separate TimesTen databases. Consequently, the content of the databases may overlap with no coordination from the cache unless your applications logically partition their data between different nodes or use read-only cache groups.

TimesTen Classic supports all cache group types; TimesTen Scaleout only supports static read-only cache groups.

See Cache Group Types in the *Oracle TimesTen In-Memory Database Cache Guide*.

Explicitly or Dynamically Loaded Cache Groups

Cache groups can loaded either explicitly or dynamically.

Cache groups can be defined as either static or dynamic to specify how they can be loaded.

- Static cache groups can only be explicitly loaded. The application preloads data into the cache tables from the Oracle database using a load cache group operation. From that point on, all data needed by the application is available in the TimesTen database.
- Dynamic cache groups can be dynamically or explicitly loaded. Cache instances are automatically loaded into the cache from the Oracle database when the application references cache instances that are not already in the cache. The use of dynamic cache groups is typically coupled with least recently used (LRU) aging so that less recently used cache instances are aged out of the cache to free up space for recently used cache instances. Using dynamic cache groups is appropriate when the size of the data that qualifies for caching exceeds the size of the memory available for the TimesTen database.

All cache group types (read-only, AWT, SWT, user managed) can be defined as static or dynamic.

See Transmitting Changes Between the TimesTen and Oracle Databases in the *Oracle TimesTen In-Memory Database Cache Guide*.

Transmitting Data Between TimesTen and an Oracle Database

TimesTen maintains consistency between cached data and the Oracle database by automatically propagating updates from cache groups to the Oracle database and automatically refreshing data in cache groups from the Oracle database.

The rest of this section includes the following topics:

- Updating a Cache Group From the Oracle Database Tables
- Updating the Oracle Database Tables From a Cache Group

Updating a Cache Group From the Oracle Database Tables

Manual refresh and autorefresh operations are used to keep a cache group synchronized with the corresponding data in the Oracle database tables.

- *Autorefresh* - An *incremental autorefresh* operation updates only records that have been modified in the Oracle database since the last refresh. Cache operations automatically perform the incremental refresh at specified time intervals. You can also specify a *full*

autorefresh operation, which automatically refreshes the entire cache group at specified time intervals.

TimesTen Scaleout only supports the incremental autorefresh option of these two options.

- *Manual refresh* - An application issues a `REFRESH CACHE GROUP` statement to refresh either an entire cache group or a specific cache instance. It is equivalent to unloading and then loading the cache group or cache instance.

These mechanisms are useful under different circumstances. A full autorefresh may be the best choice if the Oracle database table is updated only once a day and many rows are changed. An incremental autorefresh is the best choice if the Oracle database table is updated often, but only a few rows are changed with each update. A manual refresh is the best choice if the application logic knows when the refresh should happen.

See Methods for Transmitting Changes Between TimesTen and Oracle Databases in the *Oracle TimesTen In-Memory Database Cache Guide*.

Updating the Oracle Database Tables From a Cache Group

The propagate and flush mechanisms are available to keep the Oracle database up to date with the cache group.

- *Propagate* - The most common way to propagate cache group data to the Oracle database is by using an asynchronous writethrough (AWT) cache group. Other methods of updating the Oracle database tables are using a synchronous writethrough (SWT) cache group or specifying the `PROPAGATE` option in a user managed cache group.

  Changes to an AWT cache group are committed without waiting for the changes to be applied to the Oracle database tables. AWT cache groups provide better response times and performance than SWT cache groups and user managed cache groups with the `PROPAGATE` option, but the TimesTen database and the Oracle database do not always contain the same data because changes are applied to the Oracle database tables asynchronously.

  You can increase throughput from AWT cache groups to the Oracle database tables by configuring parallel replication at database creation time. You configure the number of threads for applying updates to the Oracle database tables.

- *Flush* - A flush operation can be used to propagate updates manually from a user managed cache group to the Oracle database. An application initiates a flush operation by issuing a `FLUSH CACHE GROUP` statement. Flush operations are useful when frequent updates occur for a limited period of time over a set of records. Flush operations do not propagate deletes.

For more information about autorefresh or manual refresh operations for cache groups, see Methods for Transmitting Changes Between TimesTen and Oracle databases in the *Oracle TimesTen In-Memory Database Cache Guide*.

Aging Feature

In TimesTen Classic, records can be automatically aged out of a TimesTen database, and cache instances can be automatically aged out of a TimesTen database. Aging can be usage-based or time-based.

You can configure both usage-based and time-based aging in the same system, but you can define only one type of aging on a specific cache group.

Dynamic load can be used to reload a requested cache instance that has been deleted by aging.

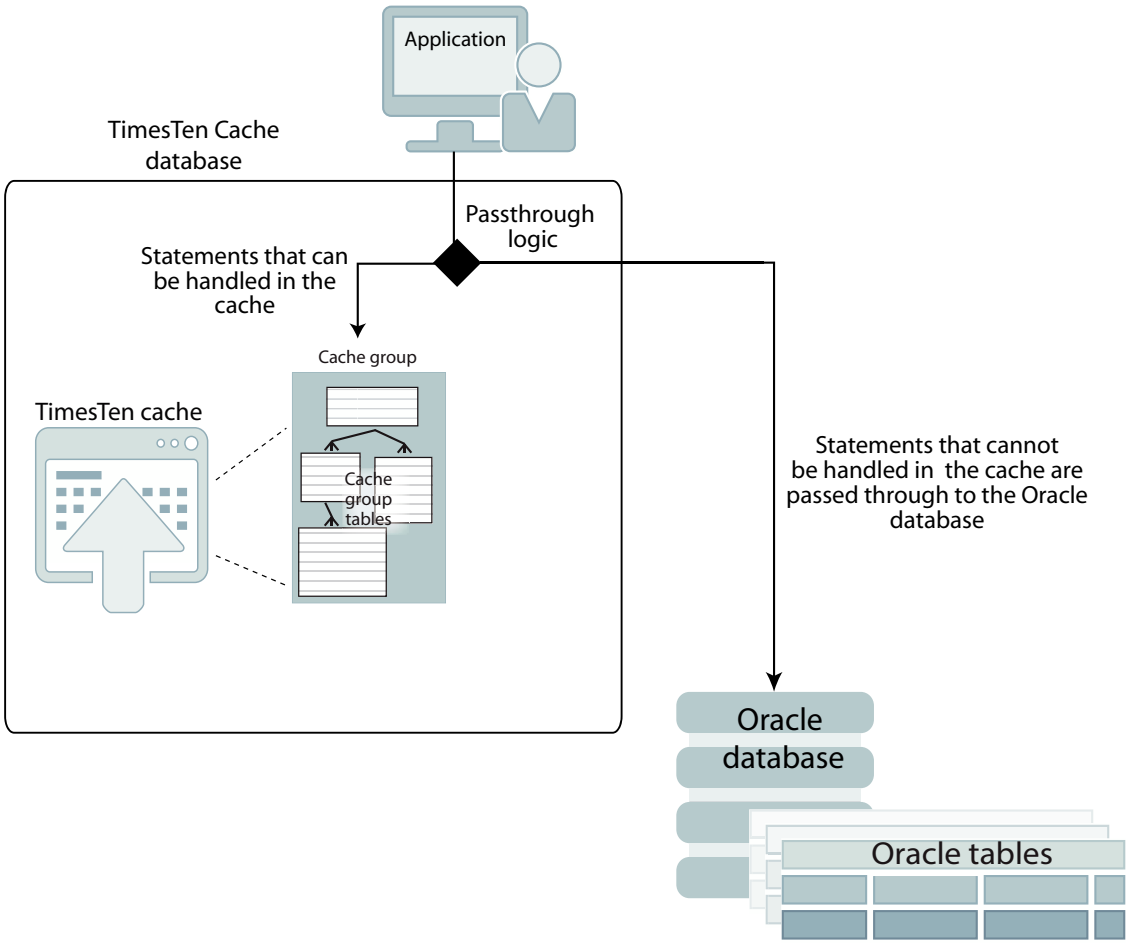
For more information about aging in cache groups, see Implementing Aging in a Cache Group in TimesTen Classic in *Oracle TimesTen In-Memory Database Cache Guide*. For information about aging in tables that are not in cache groups, see Implementing Aging Policy in Your Tables in *Oracle TimesTen In-Memory Database Operations Guide*.

Passthrough Feature

Applications use a single connection to a cache to send SQL statements to either a cache group or to the Oracle database. This single-connection capability is enabled by a *passthrough* feature that checks whether the SQL statement can be handled locally by the cached tables in TimesTen or if it must be redirected to the Oracle database.

The passthrough feature provides settings that specify what types of statements are to be passed through and under what circumstances. The specific behavior of the passthrough feature is controlled by the `PassThrough` cache general connection attribute.

Figure 7-2 Passthrough Feature



See Setting a Passthrough Level in *Oracle TimesTen In-Memory Database Cache Guide*.

Replicating Cache Groups

In TimesTen Classic, you can use an active standby pair to replicate AWT cache groups and read-only cache groups.

See Cache Groups and Replication in the *Oracle TimesTen In-Memory Database Replication Guide*.

Disaster Recovery for TimesTen Classic through Cache

In TimesTen Classic, cache supports Oracle Data Guard, as well as providing its own high availability through active standby pair replication of cache tables for read-only and AWT cache groups.

You can use the following methods to set up a disaster recovery site:

- Replicating an AWT cache group with a subscriber propagating to an Oracle database.

  You can recover from a complete site failure by creating a special disaster recovery read-only subscriber as part of the active standby pair replication scheme. The standby database sends updates to cache group tables on the read-only subscriber. This special subscriber is located at a remote disaster recovery site and can propagate updates to a second Oracle database, also located at the disaster recovery site. The disaster recovery subscriber can take over as the active in a new active standby pair at the disaster recovery site if the primary site suffers a complete failure. Any applications may then connect to the disaster recovery site and continue operating, with minimal interruption of service.

  See Using a Disaster Recovery Subscriber in an Active Standby Pair in the *Oracle TimesTen In-Memory Database Replication Guide*.

- Using cache with either synchronous or asynchronous Data Guard.

  Oracle Data Guard provides the management, monitoring, and automation software infrastructure to create and maintain one or more synchronized standby Oracle databases to protect data from failures, disasters, errors, and corruptions. If the primary Oracle database becomes unavailable because of a planned or an unplanned outage, Data Guard can switch any standby Oracle database to the primary role, thus minimizing downtime and preventing any data loss.

  – Asynchronous Data Guard support: You can cache tables from an Oracle Active Data Guard with the asynchronous redo transport mode into read-only cache groups. The read-only cache groups are replicated within an active standby pair replication scheme. The Active Data Guard configuration includes a primary Oracle database that communicates over an asynchronous transport to a single physical standby Oracle database.

  – Synchronous Data Guard support: Cache works with synchronous physical standby failover and switchover and logical standby switchover. During a transient upgrade, a physical standby Oracle database is transformed into a logical standby Oracle database.

  See Using Cache with Data Guard in the *Oracle TimesTen In-Memory Database Cache Guide*.

8

Event Notification

Event notification is done through the Transaction Log API (XLA), which provides functions to detect changes to the database.

XLA monitors log records. A log record describes an insert, update, or delete on a row in a table. XLA can be used with materialized views to focus the scope of notification on changes made to specific rows across multiple tables.

TimesTen also use SNMP traps to send asynchronous alerts of events.

This chapter includes the following topics:

- Detect Transaction Modifications With the Transaction Log API
- Monitor Tables With Materialized Views and XLA
- Monitor Problems With SNMP Traps

Detect Transaction Modifications With the Transaction Log API

TimesTen Classic provides a Transaction Log API (XLA) that enables applications to monitor the transaction log of a database to detect changes made by other applications.

XLA also provides functions that enable XLA applications to apply the detected changes to another database. XLA is a C language API. TimesTen Classic provides a C++ wrapper interface for XLA as part of TTClasses, as well as a separate Java wrapper interface.

Applications use XLA to implement a change notification scheme. In this scheme, XLA applications can monitor a database for changes and then take actions based on those changes. For example, a TimesTen database in a stock trading environment might be constantly updated from a data stream of stock quotes. Automated trading applications might use XLA to monitor the database for updates on certain stock prices and use that information to determine whether to process orders. See TimesTen Classic Application Scenario for a complete example.

XLA can also be used to build a custom data replication solution in place of the TimesTen replication. Such XLA-enabled replication solutions might involve replicating data to a non-TimesTen database.

See XLA and TimesTen Event Management in the *Oracle TimesTen In-Memory Database C Developer's Guide* and Using JMS/XLA for Event Management in *Oracle TimesTen In-Memory Database Java Developer's Guide*.

For more information about TTClasses, see Using XLA in TTClasses in the *Oracle TimesTen In-Memory Database TTClasses Guide*.

The following sections describe how XLA works in TimesTen Classic:

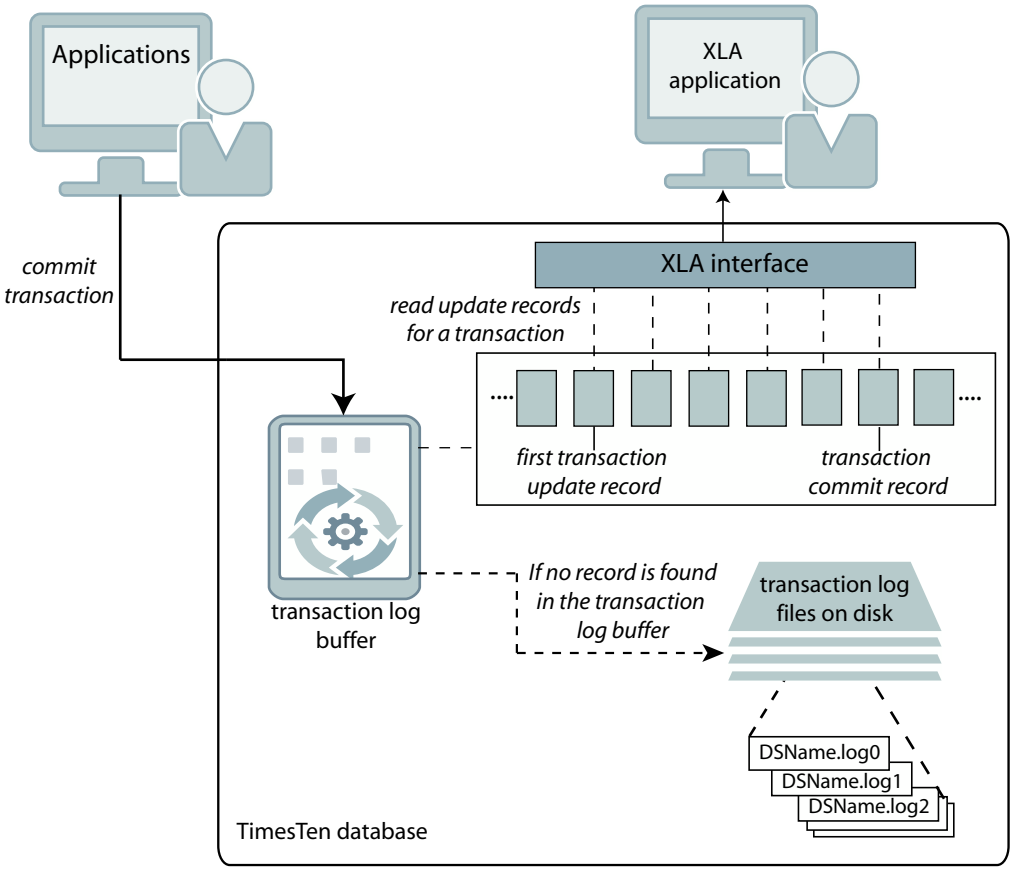
- How XLA Works
- Log Update Records

How XLA Works

XLA obtains update records for transactions directly from the transaction log buffer. If the records are not present in the buffer, XLA obtains the update records from the transaction log files.

Readers use bookmarks to maintain their position in the log update stream. Bookmarks are stored in the database, so they are persistent across database connections, shutdowns, and failures. As described in When Are Transaction Log Files Deleted?, the presence of an XLA bookmark prevents transaction log files from being deleted until the XLA log records in that transaction log file have been read and acknowledged by the XLA application.

Figure 8-1 How XLA Works



See Figure 8-1.

Log Update Records

Update records are available to be read from the log as soon as the transaction that created them commits.

A log monitoring application can obtain groups of update records written to the log. Each returned record contains a fixed-length update header and one or two rows of data stored in an internal format. The update header describes:

- The table to which the updated row applies
- Whether the record is the first or last commit record in the transaction
- The type of transaction it represents
- The length of the returned row data
- Which columns in the row were updated

Monitor Tables With Materialized Views and XLA

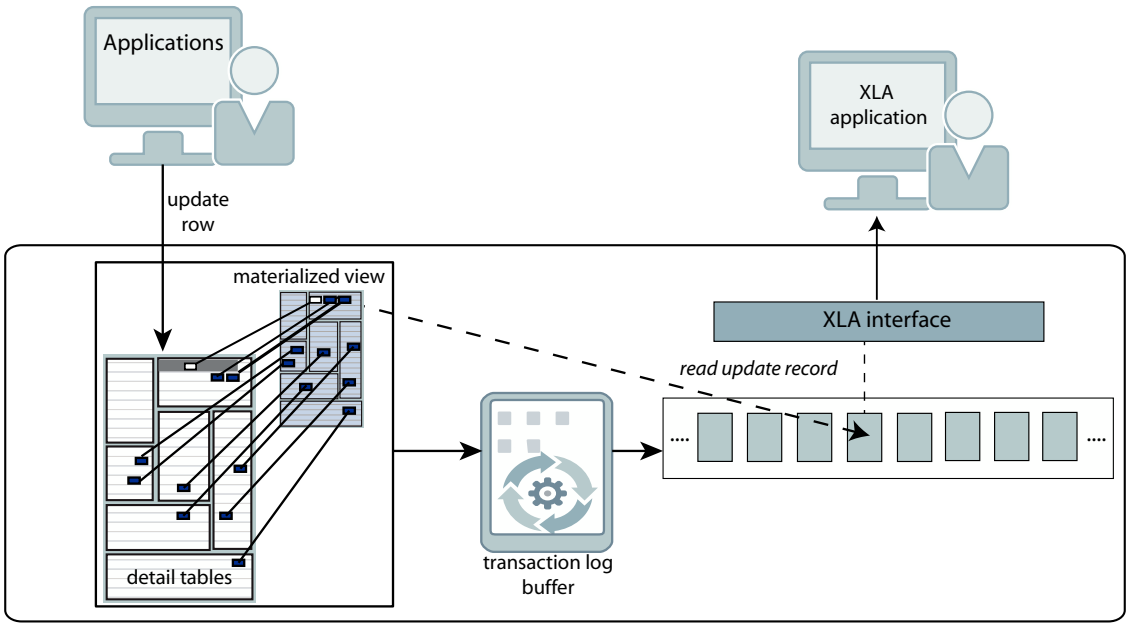
In most database systems, materialized views are used to simplify and enhance the performance of SELECT queries that involve multiple tables. Though materialized views offer this same capability in TimesTen, another purpose of materialized views in TimesTen Classic is their role in working with XLA to keep track of specific rows and columns in multiple tables.

> **Note:**
>
> See Understanding Materialized Views in *Oracle TimesTen In-Memory Database Operations Guide*. Also, see the `CREATE MATERIALIZED VIEW` statement in *Oracle TimesTen In-Memory Database SQL Reference*.

When a materialized view is present, an XLA application needs to monitor only update records that are of interest from a single materialized view. Without a materialized view, the XLA application would have to monitor all of the update records from all the detail tables of that materialized view, including records reflecting updates to rows and columns of no interest to the application.

Figure 8-2 shows an update made to a column in a detail table that is part of the materialized view result set. The XLA application monitoring updates to the materialized view captures the updated record. Updates to columns and rows in the same detail table that are not part of the materialized view are not seen by the XLA application.

Figure 8-2 Using XLA to Detect Updates on a Materialized View Table



See TimesTen Classic Application Scenario for an example of a trading application that uses XLA and a materialized view to detect updates to specific stocks.

The TimesTen implementation of materialized views emphasizes performance as well as the ability to detect updates across multiple tables. Readers familiar with other implementations of materialized views should note that the following tradeoffs have been made:

- The application must explicitly create materialized views. The TimesTen query optimizer has no facility to create materialized views automatically.
- The query optimizer does not rewrite queries on the detail tables to reference materialized views. Application queries must directly reference views.
- There are some restrictions to the SQL used to create materialized views.

Monitor Problems With SNMP Traps

Simple Network Management Protocol (SNMP) is a protocol for network management services. Network management software typically uses SNMP to query or control the state of network devices like routers and switches.

These devices sometimes also generate asynchronous alerts in the form of UDP/IP packets, called SNMP traps, to inform the management systems of problems.

TimesTen cannot be queried or controlled through SNMP. However, TimesTen sends SNMP traps for certain critical events to facilitate user recovery mechanisms.

- Cache autorefresh failure
- Database out of space
- Replicated transaction failure
- Death of daemons
- Database invalidation
- Assertion failure

These events also cause log entries to be written by the TimesTen daemon, but exposing them through SNMP traps enables properly configured network management software to take immediate action.

See Diagnostics Through SNMP Traps in *Oracle TimesTen In-Memory Database Error Messages and SNMP Traps*.

9
TimesTen Administration

This chapter includes the following topics:

Installing TimesTen

TimesTen is installed by unzipping a distribution file.

For TimesTen Scaleout, TimesTen is installed on Linux systems by unzipping the TimesTen distribution on the host of the first management instance. Use the `ttGridAdmin` utility to copy the distribution to other hosts involved in the grid. See Prerequisites and Installation of TimesTen Scaleout in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

For TimesTen Classic, TimesTen is installed by unzipping a distribution file. See Overview of the Installation Process in TimesTen Classic in the *Oracle TimesTen In-Memory Database Installation, Migration, and Upgrade Guide*.

Access Control

TimesTen is installed with access control to only allow users with specific privileges to access particular TimesTen features.

TimesTen access control uses standard SQL operations to establish user accounts with specific privileges. TimesTen offers object-level access control as well as database-level access control.

See Authorization in TimesTen in the *Oracle TimesTen In-Memory Database Security Guide*.

Command Line Administration

Most TimesTen administration tasks are performed with command line utilities.

The following table summarizes common utilities:

Name	Description
`ttAdmin`	A general utility for managing a database in TimesTen Classic. Used to specify policies for automatically or manually loading and unloading a database from RAM, as well as to starting and stopping cache agents and replication agents.
`ttBackup` and `ttRestore`	Used to create a backup copy of a database in TimesTen Classic and restore it at a later time.
`ttBulkCp`	Used to transfer data between TimesTen tables and ASCII files.
`ttGridAdmin`	A general utility for all aspects of administering TimesTen Scaleout, such as creating a grid, adding or removing data instances or management instances, creating a database, and redistributing data to new data instances.
`ttIsql`	Used to run SQL interactively from the command line, similar to Oracle SQL*Plus. Also provides a number of administrative commands to reconfigure and monitor a database.
`ttMigrate`	Used to migrate the contents of a database between major TimesTen releases.
`ttRepAdmin`	Used to monitor replication status for replication schemes in TimesTen Classic.
`ttSize`	Used to estimate the amount of space to allocate for a table in the database.
`ttStats`	Used to monitor database metrics (statistics, states, and other information). Automatically captures system snapshots, and takes and compares snapshots of metrics.
`ttStatus`	Used to display information that describes the current state of a TimesTen database.
`ttTraceMon`	Used to enable and disable the TimesTen internal tracing facilities.
`ttXactAdmin`	Used to list ownership, status, log and lock information for each outstanding transaction, as well as latches held by each connection. The `ttXactAdmin` utility also enables users of TimesTen Classic to commit, terminate or forget an XA transaction branch.

For more information about general administration of TimesTen, see Managing TimesTen Databases and Working with Data in a TimesTen Database in the *Oracle TimesTen In-Memory Database Operations Guide*. These chapters include the use of the ODBC Administrator.

For more information about administering TimesTen replication, see Overview of TimesTen Replication in the *Oracle TimesTen In-Memory Database Replication Guide*.

For information about TimesTen utilities (both general-purpose and TimesTen Scaleout-specific), see Utilities in the *Oracle TimesTen In-Memory Database Reference*.

SQL Administration

TimesTen provides SQL statements for administrative activities such as creating and managing tables, indexes, views, materialized views, synonyms, sequences, users, privileges and cache groups. TimesTen Classic provides SQL statements for creating and managing replication schemes.

Administrators can run SQL statements within the `ttIsql` utility. For example, there are several built-in `ttIsql` commands that display information on database structures.

> **Note:**
>
> For a complete list of SQL statements, see SQL Statements in the *Oracle TimesTen In-Memory Database SQL Reference*.

TimesTen stores metadata (information about the contents of your database) in system tables in your database. TimesTen also provides system views that enable you to use SQL to query information.

In addition, TimesTen provides several local (`V$`) and global (`GV$`) system views you can query to retrieve metadata information about your database.

- `V$` views: Views that return information for a TimesTen Classic database or for the element to which your application is connected in TimesTen Scaleout.
- `GV$` view: `GV$` views return the same type of information as the `V$` views, except that the information returned is global in nature as it contains the contents of the `V$` view for every element of the TimesTen Scaleout database.

See System Tables and Views in the *Oracle TimesTen In-Memory Database System Tables and Views Reference*.

SQL Developer

Oracle SQL Developer is a graphical tool for database development tasks.

SQL Developer is a Java application that supports direct-linked and client/server connections to a TimesTen database. Support for connecting to multiple databases enables SQL Developer users to work with data in the TimesTen and the Oracle databases concurrently.

- Facilitating TimesTen Scaleout Development and Management
- Facilitating TimesTen Classic Development and Management

See Prerequisites to Using SQL Developer in the *Oracle TimesTen In-Memory Database SQL Developer Support User's Guide*.

Facilitating TimesTen Scaleout Development and Management

Use SQL Developer to facilitate TimesTen Scaleout development and management.

- Create, manage, and explore a grid and its components.
- Browse, create, edit and drop particular database objects
- Run SQL statements and scripts
- Manipulate and export data
- View and create reports
- View database metrics

See Using SQL Developer in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Facilitating TimesTen Classic Development and Management

Use SQL Developer to facilitate TimesTen Classic development and management:

- Browse, create, and manage database objects and PL/SQL programs
- Automate cache group operations
- Manipulate and export data
- Run SQL and PL/SQL statements and scripts
- View and create reports
- View database metrics

ODBC Administrator

The ODBC Administrator is a utility program used on a Windows client to create, configure and delete data source definitions.

You can use it to define a data source and configure its connection attributes.

Migrating a Database

In TimesTen Scaleout, you can migrate a database from TimesTen Classic to TimesTen Scaleout.

See Migrating, Backing Up and Restoring Data in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

In TimesTen Classic, you can migrate data between major releases (for example, from TimesTen 11.2.2 to 22.1) by using the `ttMigrate` utility to export the data from the old release and import it to the new release. The `ttMigrate` utility saves database objects in a binary file and upgrades or downgrades database objects by restoring the objects from the binary file into the target database. See Migrating a Database in the *Oracle TimesTen In-Memory Database Installation, Migration, and Upgrade Guide*.

Upgrading TimesTen

There is a separate process for upgrading to a new release of TimesTen Scaleout or TimesTen Classic.

- Upgrades for a Grid in TimesTen Scaleout
- Offline Upgrades for TimesTen Classic
- Online Upgrades for TimesTen Classic

Upgrades for a Grid in TimesTen Scaleout

Upgrading a grid consists of ensuring that every instance uses for its operations the installation files provided by a newer patch release of TimesTen. For

See Upgrading a Grid in the *Oracle TimesTen In-Memory Database Scaleout User's Guide*.

Offline Upgrades for TimesTen Classic

In TimesTen Classic, offline upgrades are performed either by using the `ttInstanceModify` or the `ttMigrate` utilities.

Offline upgrades can be used to:

- Apply a patch set or a patch level within a patch set, run the `ttInstanceModify` utility to upgrade the instance and its databases.
- Move to a different major release, you must run `ttMigrate` to export the database to a flat file and then use `ttMigrate` again to import the data into the new database.

During an offline upgrade, the database is not available to applications. Offline upgrades usually require enough space on the file system for an extra copy of the upgraded database.

See Upgrades in TimesTen Classic in the *Oracle TimesTen In-Memory Database Installation, Migration, and Upgrade Guide*.

Online Upgrades for TimesTen Classic

In TimesTen Classic, replication enables online upgrades, while the database and its applications remain operational and available to users. Online upgrades are useful for applications where continuous availability of the database is critical.

Upgrading a database to a new release is performed by disconnecting all applications from one of two replicated copies of a database, making a backup of the database with the `ttMigrate` utility from the older release, loading the backup into a newer release database using the `ttMigrate` utility from the newer release, and then reconnecting all applications to the database in the upgraded instance.

See Upgrades in TimesTen Classic in the *Oracle TimesTen In-Memory Database Installation, Migration, and Upgrade Guide*.