# Managing ZFS File Systems in Oracle Solaris 11.4

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# Using This Documentation

- **Overview** – Provides information about the Oracle ZFS file system, including information specific to SPARC and x86 based systems, where appropriate.
- **Audience** – System administrators.
- **Required knowledge** – Basic Oracle Solaris or UNIX system administration experience and general file system administration experience.

## Product Documentation Library

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# Introducing the Oracle Solaris ZFS File System

This chapter provides an overview of the Oracle Solaris ZFS file system and its features and benefits. It covers the following information:

- What's New in ZFS for Oracle Solaris
- Oracle Solaris ZFS Features
- Components of a ZFS Storage Pool
- Redundancy Features of a ZFS Storage Pool

## What's New in ZFS for Oracle Solaris

The following ZFS features are introduced in this Oracle Solaris release.

- ZFS supports compressed *raw send* in data replication. With this feature, ZFS can replicate data by sending compressed file system blocks as is from the disk and writing the blocks as is to the target. The feature increases efficiency by eliminating the decompression-recompression processes in previous ZFS replication operations that used to run before the data blocks are received at the target. For more information, see Sending ZFS Data Using Raw Transfer.
- Bandwidth restrictions can now be set on a dataset. By setting bandwidth restrictions, you can assign limits to I/O operations on datasets to make sure that no one dataset can monopolize the bandwidth of the pool. For more information, see Setting I/O Bandwidth Limits.
- ZFS includes the ability to restart or resume a transfer of ZFS data. This means that you will not need to resend data that has already been received if the transfer is interrupted due to network outage or ZFS server downtime. For more information, see Using Resumable Replication.
- When you transfer ZFS data from an Oracle Solaris 11.4 system, by default per block checksums are enabled. To transfer ZFS data to systems that do not support per block checksums, see Sending ZFS Data From a Oracle Solaris 11.4.0 Dataset.
- You can remove top-level devices from a ZFS pool with the `zpool remove` command. This feature is added to the command to compliment the current capabilities of removing log, cache, and hot spare devices from pools. For more information, see Removing Devices From a Storage Pool.
- The `clustered` zpool property allows for global mounting of a ZFS file system in an Oracle Solaris Cluster environment. See Cluster documentation at https://docs.oracle.com/cd/E69294_01/index.html for more information.
- The `zfs send` command can be used to replicate a cloned dataset in a self-contained manner, independent from the origin dataset. For more information, see Types of ZFS Snapshot Streams.
- The `cp` command can be used with the `-z` option to copy a file more quickly. For more information, see Copying ZFS Files.

- The clone auto-promote feature enables you to do the following:
  - Destroy datasets even if these datasets have snapshots that are clone origins. Thus, destroying snapshots, shares or projects becomes independent of any dependent clones. These clones can be preserved even after the destroy operation.
  - Clone datasets directly without having to take a snapshot of the dataset first.
  - Provide data about disk space utilization of clones. Thus, you can understand how clones share disk space and how the space used by a clone can change as other datasets are destroyed and promoted.

# Oracle Solaris ZFS Features

The Oracle Solaris ZFS file system provides features and benefits not found in other file systems. The following table compares the features of the ZFS file system with traditional file systems.

> **Note:**
>
> For a more detailed discussion of the differences between ZFS and historical file systems, see Oracle Solaris ZFS and Traditional File System Differences.

**Table 1-1 Comparison of the ZFS File System and Traditional File Systems**

| ZFS File System | Traditional File Systems |
|---|---|
| Uses concept of *storage pools* created on devices. The pool size grows as more devices are added to the pool, The additional space is immediately available for use. | Constrained to one device and to the size of that device. |
| Volume manager unnecessary. Commands configure pools for data redundancy over multiple devices.<br>Supports one file system per user or project for easier management. | Requires volume manager to handle multiple devices to provide data redundancy, which adds to the complexity of administration.<br>Uses one file system to manage multiple subdirectories. |
| Set up and manage many file systems by issuing commands, and directly apply properties that can be inherited by the descendant file systems within the hierarchy. No need to edit the `/etc/vfstab` file. File system mounts or unmounts are automatic based on file system properties.<br>You can create a *snapshot*, a read-only copy of a file system or volume quickly and easily. Initially, snapshots consume no additional disk space within the pool. | Complex administration due to device and size constraints. For example, every time you add a new file system, you must edit the `/etc/vfstab` file. |
| Metadata is allocated dynamically. No pre-allocation or predetermined limits are set. The number of supported file systems is limited only by the available disk space. | Pre-allocation of metadata results in immediate space cost at the creation of the file system. Pre-allocation also predetermines the total number of file systems that can be supported. |
| Uses transactional semantics, where data management uses *copy-on-write* semantics, not data overwrite. Any sequence of operations is either entirely committed or entirely ignored. During accidental loss of power or a system crash, most recently written pieces of data might be lost but the file system always remains consistent and uncorrupted. | Overwrites data in place. File system vulnerable to getting into an inconsistent state, for example, if the system loses power between the time a data block is allocated and when it is linked into a directory. Tools such as `fsck` command or journaling do not always guarantee a fix and can introduce unnecessary overhead. |

**Table 1-1 (Cont.) Comparison of the ZFS File System and Traditional File Systems**

| ZFS File System | Traditional File Systems |
|---|---|
| All checksum verification and data recovery are performed at the file system layer, and are transparent to applications. All failures are detected and recovery can be performed.<br>Supports self-healing data through its varying levels of data redundancy. A bad data block can be repaired by replacing it with correct data from another redundant copy. | Checksum verification, if provided, is performed on a per-block basis. Certain failures, such as writing a complete block to an incorrect location, can result in data that is incorrect but has no checksum errors. |
| ACL (Access Control List) model based on NFSv4 specifications to protect ZFS, similar to NT-style ACL. The model provides a much more granular set of access privileges. Richer inheritance semantics designate how access privileges are applied through the directory hierarchy. | In previous Oracle Solaris releases, ACL implementation was based on POSIX ACL specifications to protect UFS. |

# Components of a ZFS Storage Pool

This section describes the components used for creating ZFS pools.

## Using Disks in a ZFS Storage Pool

The most basic element of a storage pool is physical storage. Physical storage can be any block device of at least 128 MB in size. Typically, this device is a hard drive that is visible to the system in the `/dev/dsk` directory.

A storage device can be a whole disk (`c1t0d0`) or an individual slice (`c0t0d0s7`). From management, reliability, and performance perspectives, using whole disks is the easiest and most efficient way to use ZFS. ZFS formats the whole disk to contain a single, large slice. No special disk formatting is required. With other methods, such as building pools from disk slices, LUNs in hardware RAID arrays, or volumes presented by software-based volume managers, management becomes increasingly complex and might provide less-than-optimal performance.

> **Caution:**
>
> Because of potential complexity in managing slices for storage pools, avoid using slices.

The `format` command displays the partition table of disks. When Oracle Solaris is installed on a SPARC® system with GPT aware firmware, an EFI (GPT) label is applied to the disk. The partition table would be similar to the following example:

```
Current partition table (original):
Total disk sectors available: 143358287 + 16384 (reserved sectors)

Part      Tag    Flag     First Sector         Size         Last Sector
0        usr    wm               256       68.36GB          143358320
1 unassigned    wm                 0           0               0
2 unassigned    wm                 0           0               0
3 unassigned    wm                 0           0               0
4 unassigned    wm                 0           0               0
5 unassigned    wm                 0           0               0
6 unassigned    wm                 0           0               0
8   reserved    wm         143358321        8.00MB          143374704
```

When Oracle Solaris is installed on an x86 based system, in most cases a EFI (GPT) label is applied to root pool disks. The partition table would be similar to the following:

```
Current partition table (original):
Total disk sectors available: 27246525 + 16384 (reserved sectors)

Part      Tag    Flag     First Sector         Size         Last Sector
0  BIOS_boot    wm               256     256.00MB         524543
1        usr    wm            524544      12.74GB         27246558
2 unassigned    wm                 0          0            0
3 unassigned    wm                 0          0            0
4 unassigned    wm                 0          0            0
5 unassigned    wm                 0          0            0
6 unassigned    wm                 0          0            0
8   reserved    wm          27246559       8.00MB         27262942
```

In the output, partition 0 (`BIOS boot`) contains required GPT boot information. Similar to partition 8, partition 0 requires no administration and should not be modified. The root file system is contained in partition 1.

> **Note:**
>
> For more information about EFI labels, see About EFI (GPT) Disk Labels in *Managing Devices in Oracle Solaris 11.4* .

On an x86 based system, the disk must have a valid Solaris `fdisk` partition. For more information about creating or changing an Oracle Solaris `fdisk` partition, see Configuring Disks in *Managing Devices in Oracle Solaris 11.4* .

Disk names generally follow the `/dev/dsk/cNtNdN` naming convention. Some third-party drivers use a different naming convention or place disks in a location other than the `/dev/dsk` directory. To use these disks, you must manually label the disk and allocate it to ZFS.

You can specify disks by using either the full path or a shorthand name that consists of the device name within the `/dev/dsk` directory. The following examples show valid disk names:

- `c1t0d0`
- `/dev/dsk/c1t0d0`
- `/dev/tools/disk`

## Using Files in a ZFS Storage Pool

With ZFS, you can use files as virtual devices in your storage pool. If you adopt this method, ensure that all files are specified as complete paths and are at least 64 MB in size.

This feature is useful for testing, such as experimenting with more complicated ZFS configurations when physical devices are insufficient. Do not use this feature in a production environment.

If you create a ZFS pool backed by files on a UFS file system, then you are implicitly relying on UFS to guarantee correctness and synchronous semantics. However, creating a ZFS pool backed by files or volumes that are created on another ZFS pool might cause a system deadlock or panic.

# Redundancy Features of a ZFS Storage Pool

You should configure your storage pools using ZFS redundancy. Without redundancy, the risk of losing data is great. Moreover, without ZFS redundancy, the pool can only report data inconsistencies, but cannot repair those inconsistencies. ZFS provides data redundancy and self-healing properties in mirrored and RAID-Z configurations.

## Mirrored Storage Pool Configuration

A mirrored storage pool configuration requires at least two disks, preferably on separate controllers. A mirrored configuration can be simple or complex, where more than one mirror exists in each pool.

For information about creating simple or complex mirrored storage pools, see Creating a Mirrored Storage Pool.

## RAID-Z Storage Pool Configuration

ZFS supports a RAID-Z configuration with the following fault tolerance levels:

- Single-parity (`raidz` or `raidz1`) – Similar to RAID-5.
- Double-parity (`raidz2`) – Similar to RAID-6.
- Triple-parity (`raidz3`) – For more information, see Triple-Parity RAID and Beyond (https://queue.acm.org/detail.cfm?id=1670144).

In RAID-Z, ZFS uses variable-width RAID stripes so that all writes are full-stripe writes. ZFS integrates file system and device management in such a way that the file system's metadata has enough information about the underlying data redundancy model to handle variable-width RAID stripes. Thus, RAID-Z avoids issues encountered in traditional RAID algorithms such as RAID-5's *write hole* problem.

ZFS provides self-healing data in a mirrored or RAID-Z configuration. When a bad data block is detected, ZFS fetches the correct data from another redundant copy and repairs the bad data by replacing it with the good copy.

A RAID-Z configuration with *n* disks of size *x* with *p* parity disks can hold approximately (*n-p*)**x* bytes and can withstand *p* devices failing before data integrity is compromised. You need at least two disks for a single-parity RAID-Z configuration and at least three disks for a double-parity RAID-Z configuration, and so on. For example, if you have three disks in a single-parity RAID-Z configuration, parity data occupies disk space equal to one of the three disks. Otherwise, no special hardware is required to create a RAID-Z configuration.

Just like mirrored configurations, RAID-Z configurations can either be simple or complex.

If you are creating a RAID-Z configuration with many disks, consider splitting the disks into multiple groupings. For example, a RAID-Z configuration with 14 disks is better split into two 7-disk groupings. RAID-Z configurations with single-digit groupings of disks commonly perform better.

See the following sources for more information:

- Creating a RAID-Z Storage Pool – provides information about creating a RAID-Z storage pool.

- *When to (and Not to) Use RAID-Z* – presents guidelines on choosing between a mirrored configuration or a RAID-Z configuration based on performance and disk space considerations.
- Recommended Oracle Solaris ZFS Practices – covers additional RAID-Z storage pool recommendations.

## ZFS Hybrid Storage Pool

The ZFS hybrid storage pool, available in Oracle's Sun Storage 7000 product series, combines DRAM, SSDs, and HDDs to improve performance and increase capacity, while reducing power consumption. With this product's management interface, you can select the ZFS redundancy configuration of the storage pool and easily manage other configuration options.

For more information, see Oracle Unified Storage Systems (https://docs.oracle.com/cd/F24631_01/index.html).

## Dynamic Striping in a Storage Pool

ZFS dynamically stripes data across all top-level virtual devices. The decision about where to place data is done at write time, so no fixed-width stripes are created at allocation time.

When new virtual devices are added to a pool, ZFS gradually allocates data to the new device in order to maintain performance and disk space allocation policies. Each virtual device can also be a mirror or a RAID-Z device that contains other disk devices or files. This configuration gives you flexibility in controlling the fault characteristics of your pool. For example, you could create the following configurations out of four disks:

- Four disks using dynamic striping
- One four-way RAID-Z configuration
- Two two-way mirrors using dynamic striping

To ensure efficient use of ZFS, use top-level virtual devices of the same type with the same redundancy level in each device. Do not combine different types of virtual devices within the same pool, such as using a two-way mirror and a three-way RAID-Z configuration.

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# Getting Started With Oracle Solaris ZFS

This chapter provides information to help you set up a basic Oracle Solaris ZFS configuration. Later chapters provide more detailed information. By the end of this chapter, you will have a basic understanding of how the ZFS commands work and should be able to create a basic pool and file systems.

This chapter covers the following topics:

- Hardware and Software Requirements
- Planning the ZFS Implementation

## Hardware and Software Requirements

Ensure that you meet the following hardware requirements before using the ZFS software:

- A SPARC® or x86 based system that is running a supported Oracle Solaris release.
- Between 7 GB -13 GB of disk space. For information about how ZFS uses disk space, see ZFS Root Pool Space Requirements.
- Sufficient memory to support your workload.
- Multiple controllers for mirrored pool configurations.

Additionally, to perform ZFS management tasks, you must assume a role with either of the following profiles:

- ZFS Storage Management – Provides the privilege to create, destroy, and manipulate devices within a ZFS storage pool
- ZFS File System Management – Provides the privilege to create, destroy, and modify ZFS file systems

Although you can use a superuser (`root`) account to configure ZFS, using RBAC (role-based access control) roles is a best-practice method. For more information about creating or assigning roles, see *Securing Users and Processes in Oracle Solaris 11.4* .

In addition to using RBAC roles for administering ZFS file systems, you might also consider using ZFS delegated administration for distributed ZFS administration tasks. For more information, see Oracle Solaris ZFS Delegated Administration.

## Planning the ZFS Implementation

This section describes factors you need to consider before configuring ZFS.

### Naming ZFS Components

Each ZFS component, such as datasets and pools, must be named according to the following rules:

- Each component can contain only alphanumeric characters in addition to the following special characters:

  - Underscore (_)
  - Hyphen (-)
  - Colon (:)
  - Period (.)
  - Blank (" ")

> **Note:**
>
> Tabs and other white spaces are not valid.

- Pool names must begin with a letter and can contain only alphanumeric characters as well as underscore (_), dash (-), and period (.). Note the following pool name restrictions:
  - The beginning sequence `c [0-9]` is not allowed.
  - The name `log` is reserved.
  - A name that begins with `mirror`, `raidz`, `raidz1`, `raidz2`, `raidz3`, or `spare` is not allowed because these names are reserved.
  - Pool names must not contain a percent sign (`%`).
- Dataset names must begin with an alphanumeric character.
- Dataset names must not contain a percent sign (`%`).
- Empty components are not allowed.

## Identifying Storage Requirements

The pool describes the physical characteristics of the storage. You must be create the pool before any file systems.

Before creating a storage pool, determine which devices will store your data. These devices must be disks of at least 128 MB in size, and they must not be in use by other parts of the operating system. Allocate entire disks to ZFS rather than individual slices on a preformatted disk.

For more information about disks and how they are used and labeled, see Using Disks in a ZFS Storage Pool.

## Choosing the Type of Data Redundancy

ZFS supports multiple types of data redundancy, which determines the types of hardware failures the pool can withstand. ZFS supports nonredundant (striped) configurations, as well as mirroring and RAID-Z, which is a variation on RAID-5.

For more information about ZFS redundancy features, see Redundancy Features of a ZFS Storage Pool.

## Determining the ZFS File System Hierarchy

File system hierarchies are created on pools.

Hierarchies are simple, easy to understand, yet powerful mechanisms for organizing information. This section describes specific issues regarding hierarchy planning.

## Selecting the File System Granularity

ZFS supports file systems organized into hierarchies, where each file system has only a single parent. The root of the hierarchy is always the pool name. ZFS supports property inheritance so that common you can set properties quickly and easily on entire trees of file systems by using hierarchies.

ZFS file systems provide a central point of administration. They are lightweight enough that you can establish one file system per user or project. This model enables you to control properties, snapshots, and backups on a per-user or per-project basis.

For more information about managing file systems, see Managing Oracle Solaris ZFS File Systems.

## Grouping File Systems

You can group similar ZFS file systems into hierarchies under a common name. The hierarchy becomes the central point for administering and controlling file systems and their properties.

In Configuring a Mirrored ZFS File System, the two file systems are placed under a file system named `home`.

## Choosing File System Properties

You determine most file system characteristics properties. These properties control a variety of behaviors, including where the file systems are mounted, how they are shared, whether they use compression, or whether any quotas are in effect.

For more information about properties, see Introducing ZFS Properties.

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# Creating and Destroying Oracle Solaris ZFS Storage Pools

This chapter describes how to create and destroy ZFS storage pools in Oracle Solaris. It covers the following topics:

- Creating ZFS Storage Pools
- Destroying ZFS Storage Pools

## Creating ZFS Storage Pools

This section describes different ways of configuring storage pools. For information about root pools, see Managing the ZFS Root Pool.

When you create a storage pool, you configure virtual devices for the pool. A *virtual device* is an internal representation of the disk devices or files that are used to create the storage pool and describes the layout of physical storage and the storage pool's fault characteristics. A pool can have any number of virtual devices at the top of the configuration, known as a pool's *top-level vdev*.

If the top-level virtual device contains two or more physical devices, the configuration provides data redundancy as mirror or RAID-Z virtual devices. Because of the advantages of redundancy, you should create redundant storage pools. ZFS dynamically stripes data among all of the top-level virtual devices in a pool.

Even with a redundant configuration, make sure that you also schedule regular backups of your pool data to non-enterprise grade hardware. Storage pools with ZFS redundancy are not immune to hardware failures, power failures, or disconnected cables. Performing regular backups adds another layer of data protection to your enterprise.

After you create the storage pool, you can display information about it by using the following command:

```
$ zpool status pool
```

For more options that you can use with the `zpool status` command, see Querying ZFS Storage Pool Status.

Observe the following restrictions when creating storage pools:

- Do not repartition or relabel disks that are part of an existing storage pool. Otherwise, you might have to reinstall the OS.
- Do not create a storage pool that contains components from another storage pool, such as files or volumes. Such a configuration can cause deadlocks.
- Do not create a pool to be shared across systems, which is an unsupported configuration. ZFS is not a cluster file system.

### How to Set Up ZFS on a System

1. **Assume the root role or an equivalent role with the appropriate ZFS rights profile.**

For more information about the ZFS rights profiles, see Hardware and Software Requirements.

2. **Create the ZFS pool.**

```
$ zpool create pool keyword devices [keyword devices]
```

***pool***

Name of the ZFS pool. The pool name must satisfy the naming requirements in Naming ZFS Components

***keyword***

Further specifies the pool configuration such as type of redundancy, or whether log devices or cache will be used.

For the redundancy type, you use either the keyword `mirror` for a mirrored configuration or one of the following keywords for a RAID-Z configuration, depending on the parity you want: `raidz` or `raidz1` for single parity, `raidz2` for double parity, and `raidz3` for triple parity.

***devices***

Specify the devices that are allocated for the pool. The devices cannot be in use or contain another file system. Otherwise, pool creation fails.

For more information about how device usage is determined, see Devices Actively Being Used.

3. **Display a list of ZFS pools on the system.**

```
$ zpool list
```

4. **Display the status of the pool.**

```
$ zpool status pool
```

5. **Build the file system hierarchy.**

   a. **Create the basic file system.**

   The basic file system acts as a container for the individual file systems that are subsequently created.

   ```
   $ zfs create pool/filesystem
   ```

   where *filesystem* is the name of the file system.

   When used in a command, the file system name must always include the full path of the hierarchy: *pool/filesystem*. This rule also applies to subsequent children file systems that you create.

   b. **Set the properties to be shared by children file systems.**

   ```
   $ zfs set property=value pool/filesystem
   ```

   You can set multiple system properties.

> **Tip:**
>
> You can simultaneously create a file system and set its properties by using the following syntax:
>
> ```
> $ zfs create -o property=value [-o property=value] pool/filesystem
> ```

c. **Create the individual file systems that are grouped under the basic file system.**

```
$ zfs create pool/filesystem/fs1
$ zfs create pool/filesystem/fs2
...
```

where *fs1*, *fs2*, and so on are individual file systems.

d. **Set properties specific to the individual file system.**

```
$ zfs set property=value pool/filesystem/fs1
```

6. **View the final results.**

```
$ zpool list
```

For more information about viewing pool status, see Querying ZFS Storage Pool Status.

**Example 3-1 Configuring a Mirrored ZFS File System**

In the following example, a basic ZFS configuration is created on the system with the following specifications:

- Two disks are allocated to the ZFS file system: `c1t0d0` and `c2t0d0`.
- The pool `system1` uses mirroring.
- The file system `home` is created over the pool.
- The following properties are set for `home`: `mountpoint`, `share.nfs`, and `compression`.
- Two children file systems, `user1` and `user2` are created on `home`.
- A quota is set for `user2`. This property restricts the disk space available for `user2` regardless of the available disk space of the entire pool.

The command `zfs get` used example displays file system properties.

```
$ zpool create system1 mirror c1t0d0 c2t0d0
$ zpool list
NAME       SIZE     ALLOC     FREE     CAP     HEALTH     ALTROOT
system1     80G     137K       80G      0%     ONLINE     -
$ zpool status system1
pool: system1
state: ONLINE
scrub: none requested
config:

NAME          STATE     READ  WRITE  CKSUM
system1       ONLINE       0      0      0
   mirror-0   ONLINE       0      0      0
      c1t0d0  ONLINE       0      0      0
      c2t0d0  ONLINE       0      0      0

errors: No known data errors
$ zfs create system1/home
```

```
$ zfs set mountpoint=/export/zfs system1/home
$ zfs set share.nfs=on system1/home
$ zfs set compression=on system1/home
$ zfs get compression system1/home
NAME             PROPERTY       VALUE     SOURCE
system1/home     compression    on        local
$ zfs create system1/home/user1
$ zfs create system1/home/user2
$ zfs set quota=10G system1/home/user2
$ zfs list
NAME                     USED  AVAIL  REFER  MOUNTPOINT
system1                 92.0K  67.0G   9.5K  /system1
system1/home            24.0K  67.0G     8K  /export/zfs
system1/home/user1         8K  67.0G     8K  /export/zfs/user1
system1/home/user2         8K  10.0G     8K  /export/zfs/user2
```

### Example 3-2 Configuring a RAID-Z ZFS File System

This example creates a RAID-Z file system and shows how you can specify disks by using either their shorthand device names or their full device names: the disk `c6t0d0` is the same as `/dev/dsk/c6t0d0`.

- Three disks are allocated to the ZFS file system: `c4t0d0`, `c5t0d0`, and `c6t0d0`.
- The pool `rdpool` uses a RAID-Z single-parity configuration.
- The file system `base` is created over the pool.

```
$ zpool create rdpool raidz c4t0d0 c5t0d0 /dev/dsk/c6t0d0
$ zpool list
NAME       SIZE     ALLOC     FREE     CAP     HEALTH     ALTROOT
rdpool     120G     205K      120G      0%     ONLINE     -
$ zpool status -v rdpool
  pool: rdpool
 state: ONLINE
 scrub: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        rdpool      ONLINE       0     0     0
          raidz-0   ONLINE       0     0     0
            c4t0d0  ONLINE       0     0     0
            c5t0d0  ONLINE       0     0     0
            c6t0d0  ONLINE       0     0     0

errors: No known data errors
$ zfs create rdpool/base
$ zfs set mountpoint=/export/zfs rdpool/base
$ zfs set share.nfs=on rdpool/base
$ zfs set compression=on rdpool/base
$ zfs get compression rdpool/home
NAME               PROPERTY       VALUE     SOURCE
rdpool/base        compression    on        local
$ zfs create rdpool/base/user1
$ zfs create rdpool/base/user2
$ zfs set quota=10G rdpool/base/user2
$ zfs list
NAME                   USED  AVAIL  REFER  MOUNTPOINT
rdpool                 92.0K  67.0G   9.5K  /rdpool
rdpool/base            24.0K  67.0G     8K  /export/zfs
rdpool/base/user1         8K  67.0G     8K  /export/zfs/user1
rdpool/base/user2         8K  10.0G     8K  /export/zfs/user2
```

## Creating a Mirrored Storage Pool

To create a mirrored pool, use the `mirror` keyword. To configure multiple mirrors, repeat the keyword on the command line. The following command creates a pool `system1` with two top-level virtual devices.

```
zpool create system1 mirror c1d0 c2d0 mirror c3d0 c4d0
```

Both virtual devices are two-way mirrors. Data is dynamically striped across both mirrors, with data being redundant between each disk appropriately.

For more information about recommended mirrored configurations, see Recommended Oracle Solaris ZFS Practices.

You can perform the following operations on ZFS mirrored configurations:

- Add another top-level virtual device with a different set of disks. See Adding Devices to a Storage Pool.
- Attach additional disks. See Attaching and Detaching Devices in a Storage Pool.
- Replace disks. See Replacing Devices in a Storage Pool.
- Detach disks. See Attaching and Detaching Devices in a Storage Pool.
- Split a mirrored configuration to create a new, identical pool. See Splitting a Mirrored Storage Pool to Create a New Pool.

For an example of how to configure ZFS with a mirrored storage pool, see Configuring a Mirrored ZFS File System.

## Creating a RAID-Z Storage Pool

To create a storage pool with a RAID-Z configuration, use one of the RAID-Z keywords depending on the parity that you want for the pool:

- `raidz` or `raidz1` for single-parity configuration.
- `raidz2` for double-parity configuration.
- `raidz3` for triple-parity configuration.

To create multiple RAID-Z top level virtual devices, repeat the keyword on the command line. The following command creates a pool `rdpool` with one top-level virtual device. The virtual device is a triple-parity RAID-Z configuration that consists of nine disks.

```
$ zpool create rdpool raidz3 c0t0d0 c1t0d0 c2t0d0 c3t0d0 c4t0d0 \
c5t0d0 c6t0d0 c7t0d0 c8t0d0
```

For an example of how to configure ZFS with a RAID-Z storage pool, see Configuring a RAID-Z ZFS File System.

You can perform the following operations on ZFS RAID-Z configurations:

- Add another top-level virtual device with a different set of disks. See Adding Devices to a Storage Pool.
- Replace disks. See Replacing Devices in a Storage Pool.

You cannot perform the following operations on a RAID-Z configuration:

- Attach an additional disk.

- Detach a disk, except when you are replacing it with a spare disk, or when you need to detach a spare disk.
- Remove a device that is not a log device or a cache device.

## Creating a ZFS Storage Pool With Log Devices

The ZFS intent log (ZIL) satisfies POSIX requirements for synchronous transactions. For example, databases often require their transactions to be on stable storage devices when returning from a system call. NFS and other applications can also use `fsync` to ensure data stability.

By default, the ZIL is allocated from blocks within the main pool. However, you can obtain better performance by using separate intent log devices such as NVRAM or a dedicated disk.

Log devices for the ZFS intent log are not related to database log files. Deploying separate log devices can improve performance but the improvement also depends on the device type, the hardware configuration of the pool, and the application workload.

You can configure mirrored log devices only for redundancy and not RAID-Z log devices. If an unmirrored log device fails, storing log blocks reverts to the storage pool. Further, you can add, replace, remove, attach, detach, import, and export log devices as part of the larger storage pool.

Consider the following points about ZFS log devices:

- The minimum size of a log device is the same as the minimum size of each device in a pool, which is 64 MB. The amount of logged data that might be stored on a log device is relatively small. Log blocks are freed when the log transaction or system call is committed.
- The maximum size of a log device should be approximately half the size of physical memory, which is the maximum amount of potential logged data that can be stored. For example, if a system has 16 GB of physical memory, consider a maximum log device size of 8 GB.

To create a storage pool with log devices, use the `log` keyword. The following example shows how to configure a mirrored storage pool called `datap` with a mirrored log device.

```
$ zpool create datap mirror c0t5000C500335F95E3d0 c0t5000C500335F907Fd0 \
mirror c0t5000C500335BD117d0 c0t5000C500335DC60Fd0 \
log mirror c0t5000C500335E106Bd0 c0t5000C500335FC3E7d0

$ zpool status datap
pool: datap
state: ONLINE
scrub: none requested
config:

NAME                       STATE     READ  WRITE  CKSUM
datap                      ONLINE       0      0      0
   mirror-0                ONLINE       0      0      0
      c0t5000C500335F95E3d0  ONLINE       0      0      0
      c0t5000C500335F907Fd0  ONLINE       0      0      0
   mirror-1                ONLINE       0      0      0
      c0t5000C500335BD117d0  ONLINE       0      0      0
      c0t5000C500335DC60Fd0  ONLINE       0      0      0
   logs
   mirror-2                ONLINE       0      0      0
      c0t5000C500335E106Bd0  ONLINE       0      0      0
      c0t5000C500335FC3E7d0  ONLINE       0      0      0
```

```
errors: No known data errors
```

## Creating a ZFS Storage Pool With Cache Devices

Cache devices provide an additional layer of caching between main memory and disk. These devices provide the greatest performance improvement for random-read workloads of mostly static content.

To configure a storage pool with cache devices, use the `cache` keyword, for example:

```
$ zpool create system1 mirror c2t0d0 c2t1d0 c2t3d0 cache c2t5d0 c2t8d0
$ zpool status system1
pool: system1
state: ONLINE
scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
system1        ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
      c2t0d0   ONLINE       0      0      0
      c2t1d0   ONLINE       0      0      0
      c2t3d0   ONLINE       0      0      0
   cache
      c2t5d0   ONLINE       0      0      0
      c2t8d0   ONLINE       0      0      0

errors: No known data errors
```

You can add single or multiple cache devices to the pool, either while it is being created or after it is created, as shown in Adding Cache Devices. However, you cannot create mirrored cache devices or create them as part of a RAID-Z configuration.

> **Note:**
>
> If a read error is encountered on a cache device, that read I/O is reissued to the original storage pool device, which might be part of a mirrored or a RAID-Z configuration. The content of cache devices is considered volatile, similar to other system caches.

After cache devices are added, they gradually fill with content from main memory. The time before a cache device reaches full capacity varies depending on its size. Use the `zpool iostat` command to monitor capacity and reads, as shown in the following example:

```
$ zpool iostat -v pool 5
```

For more information about the `zpool iostat` command, see Viewing I/O Statistics for ZFS Storage Pools.

## Doing a Dry Run of Storage Pool Creation

For testing purposes, you can simulate creating a pool without actually writing to the device. The `zpool create -n` command performs the device in-use checking and redundancy-level validation, and reports any errors in the process. If no errors are found, you see output similar to the following example:

```
$ zpool create -n system1 mirror c1t0d0 c1t1d0
would create 'system1' with the following layout:

system1
  mirror
    c1t0d0
    c1t1d0
```

> **Caution:**
>
> Some errors, such as specifying the same device twice in the same configuration, cannot be detected without actually creating the pool. Therefore, the actual pool creation can still fail even if the dry run is successful.

# Handling ZFS Storage Pool Creation Issues

This section groups descriptions of errors during pool creation by those relating to devices, redundancy, or mount points.

Some error messages suggest using the `-f` option to override the reported errors. However, as a general rule, you should repair errors instead of overriding them.

## Devices Actively Being Used

When you create ZFS pools on specific devices, ZFS first determines if those devices are in use either by ZFS itself or some other part of the operating system. If the devices are in use, then appropriate error messages are displayed.

You must manually correct the errors reported by the following messages before attempting to create the pool again.

**Mounted file system**
The disk contains a file system that is currently mounted. To correct this error, use the `umount` command.

**File system in /etc/vfstab**
The disk contains a file system that is listed in the `/etc/vfstab` file but the file system is not currently mounted. To correct this error, remove or comment out the line in the `/etc/vfstab` file.

**Dedicated dump device**
The disk is in use as the dedicated dump device for the system. To correct this error, use the `dumpadm` command.

**Part of a ZFS pool**
The disk or file is part of an active ZFS storage pool. To correct this error, use the `zpool destroy` command to destroy the other pool provided that the pool is no longer needed. If that pool is still needed, use the `zpool detach` command to detach the disk from that pool. You can detach a disk only from a mirrored storage pool.

The following in-use checks serve as helpful warnings. You can override these warnings by using the `-f` option to create the pool:

**Contains a file system**
The disk contains a known file system but it is not mounted or being used.

**Part of volume**
The disk is part of a Solaris Volume Manager volume.

**Part of exported ZFS pool**
The disk is part of a storage pool that has been exported or manually removed from a system. In the latter case, the pool is reported as `potentially active` because the disk might be a network-attached drive in use by another system. Be cautious when overriding a potentially active pool.

## Mismatched Redundancy Levels

Creating pools with virtual devices of different redundancy levels results in error messages similar to the following example:

```
$ zpool create system1 mirror c1t0d0 c2t0d0 mirror c3t0d0 c4t0d0 c5t0d0
invalid vdev specification
use '-f' to override the following errors:
mismatched replication level: 2-way mirror and 3-way mirror vdevs are present
```

Similar error messages are generated if you create mirrored or RAID-Z pools using devices of different sizes.

Maintaining mismatched levels of redundancy results in unused disk space on the larger device, which is an inefficient use of ZFS. You should correct these errors instead of overriding them.

## Default Mount Point for Storage Pools Not Empty

When a pool is created, the default mount point for the top-level file system is */pool-name*. If this directory exists and contains data, an error occurs.

To create a pool with a different default mount point, use the `zpool create -m` *mountpoint* command. For example:

```
$ zpool create system1 c1t0d0
default mountpoint '/system1' exists and is not empty
use '-m' option to provide a different default
$ zpool create -m /export/zfs system1 c1t0d0
```

This command creates the new pool `system1` and the `system1` file system with a mount point of `/export/zfs`.

For more information about mount points, see Managing ZFS Mount Points.

# Destroying ZFS Storage Pools

You can destroy a pool even if the pool contains mounted datasets by using the `zpool destroy` *pool* command.

> **Caution:**
>
> ZFS cannot always keep track of which devices are in use. Ensure that you are destroying the correct pool and you always have copies of your data. If you accidentally destroy the wrong pool, see Recovering Destroyed ZFS Storage Pools.

When you destroy a pool, the pool is still available for import. Therefore, confidential data might remain on the disks that were part of the pool. To completely destroy the data, use a feature like the `format` utility's `analyze->purge` option on every disk in the destroyed pool.

To ensure data confidentiality, create encrypted ZFS file systems. Even if a destroyed pool is recovered, the data would remain inaccessible without the encryption keys. For more information, see Encrypting ZFS File Systems.

When a pool with a mix of available and unavailable devices is destroyed, data is written to the available disks to indicate that the pool is no longer valid. This state information prevents the devices from being listed as a potential pool when you perform an import. Even with unavailable devices, the pool can still be destroyed. When the unavailable devices are repaired, they are reported as `potentially active` when you create a new pool and appear as valid devices when you search for pools to import.

A pool itself can become unavailable if a sufficient number of its devices are unavailable. The state of the pool's top-level virtual device is reported as `UNAVAIL`. In this case, you can destroy the pool only by using the `zpool destroy -f` command.

For more information about pool and device health, see Determining the Health Status of ZFS Storage Pools.

4

# Managing Devices in Oracle Solaris ZFS Storage Pools

This chapter discusses different tasks you can perform to manage the physical devices that you use for the ZFS pools on the system. It has the following sections:



## Adding Devices to a Storage Pool

You can dynamically add disk space to a pool by adding a new top-level virtual device. This disk space is immediately available to all datasets in the pool.

The virtual device that you add should have the same level of redundancy as the existing virtual device. However, you can change the level of redundancy by using the `-f` option.

To add a new virtual device to a pool, use the `zpool add` command.

```
$ zpool add pool keyword devices
```

> **Note:**
>
> With `zpool add -n`, you can perform a dry run before actually adding devices.

**Example 4-1 Adding Disks to a Mirrored ZFS Configuration**

In the following example, a mirror is added to a ZFS configuration that consists of two top-level mirrored devices.

```
$ zpool add mpool mirror c0t3d0 c1t3d0
$ zpool status mpool
pool: mpool
state: ONLINE
scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
mpool          ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
```

```
      c0t1d0   ONLINE       0      0      0
      c1t1d0   ONLINE       0      0      0
   mirror-1    ONLINE       0      0      0
      c0t2d0   ONLINE       0      0      0
      c1t2d0   ONLINE       0      0      0
   mirror-2    ONLINE       0      0      0Added mirrored device.
      c0t3d0   ONLINE       0      0      0
      c1t3d0   ONLINE       0      0      0

errors: No known data errors
```

### Example 4-2 Adding Disks to a RAID-Z Configuration

This example shows how to add one RAID-Z device consisting of three disks to an existing RAID-Z storage pool that also contains three disks.

```
$ zpool add rzpool raidz c2t2d0 c2t3d0 c2t4d0
$ zpool status rzpool
pool: rzpool
state: ONLINE
scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
rzpool         ONLINE       0      0      0
   raidz1-0    ONLINE       0      0      0
      c1t2d0   ONLINE       0      0      0
      c1t3d0   ONLINE       0      0      0
      c1t4d0   ONLINE       0      0      0
   raidz1-1    ONLINE       0      0      0Added RAID-Z device.
      c2t2d0   ONLINE       0      0      0
      c2t3d0   ONLINE       0      0      0
      c2t4d0   ONLINE       0      0      0

errors: No known data errors
```

### Example 4-3 Adding a Mirrored Log Device

This example shows how to add a mirrored log device to a mirrored storage pool.

```
$ zpool add newpool log mirror c0t6d0 c0t7d0
$ zpool status newpool
pool: newpool
state: ONLINE
scrub: none requested
config:


NAME           STATE     READ  WRITE  CKSUM
newpool        ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
      c0t4d0   ONLINE       0      0      0
      c0t5d0   ONLINE       0      0      0
logs                                       Added mirrored log device.
   mirror-1    ONLINE       0      0      0
      c0t6d0   ONLINE       0      0      0
      c0t7d0   ONLINE       0      0      0

errors: No known data errors
```

Note that mirrored log devices are provided with an identifier, such as `mirror-1` in the example. The identifier is useful when you remove log devices, as shown in Removing a Mirrored Log Device.

**Example 4-4 Adding Cache Devices**

This example shows how to add a cache device to a pool.

```
$ zpool add system1 cache c2t5d0 c2t8d0
$ zpool status system1
pool: system1
state: ONLINE
scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
system1        ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
      c2t0d0   ONLINE       0      0      0
      c2t1d0   ONLINE       0      0      0
      c2t3d0   ONLINE       0      0      0
   cache                                   Added cache device.
      c2t5d0   ONLINE       0      0      0
      c2t8d0   ONLINE       0      0      0

errors: No known data errors
```

# Removing Devices From a Storage Pool

To remove devices from a pool, use the `zpool remove` command. This command supports removing hot spares, cache, log, and top level virtual data devices. You can remove devices by referring to their identifiers, such as `mirror-1` in Adding Disks to a Mirrored ZFS Configuration.

You can cancel a top-level device removal operation by using the command `zpool remove -s`.

> **Note:**
>
> The primary use case for removing a top-level data device is when you accidentally add a device to a pool. You can lessen the potential impact to the running system if you remove the accidentally added device promptly. For example, system or application performance might be impacted negatively if you remove a top-level data device from an existing pool while reading a large amount of cold data that is not re-written after the device is removed. Such a process might be an RMAN backup of a data warehouse database. So, only use the `zpool remove` command to recover a pool when you have added another device to the pool accidentally. Avoid using the `zpool remove` command in cases where you cannot tolerate a performance degradation or when the pool is nearly full. In such cases, consider creating a new pool and then using the `zfs send` and `zfs recv` commands to migrate the data to the new pool.

**Example 4-5 Removing Top Level Virtual Data Devices**

This example shows how to remove `mirror-1` and `mirror-2` from the pool that was created in Adding Disks to a Mirrored ZFS Configuration. The example provides two pieces of information after you issue the command to remove devices:

- The status of the pool while the devices are being removed.
- The status of the pool after the device removal is completed.

```
$ zpool remove mpool mirror-1 mirror-2
# zpool status mpool
  pool: mpool
 state: ONLINE
status: One or more devices is currently being removed.
action: Wait for the resilver to complete.
        Run 'zpool status -v' to see device specific details.
  scan: resilver  in  progress  since  Mon Jul 7 18:19:35
        2014
        16.7G scanned
        884M  resilvered at 52.6M/s,  9.94% done, 0h1m to go
config:

NAME           STATE    READ WRITE CKSUM
mpool          ONLINE      0     0     0
   mirror-0    ONLINE      0     0     0
      c0t1d0   ONLINE      0     0     0
      c1t1d0   ONLINE      0     0     0
   mirror-1  REMOVING      0     0     0
      c0t2d0   ONLINE      0     0     0
      c1t2d0   ONLINE      0     0     0
   mirror-2  REMOVING      0     0     0
      c0t3d0   ONLINE      0     0     0
      c1t3d0   ONLINE      0     0     0
+
+         errors: No known data errors

$ zpool status mpool
pool: mpool
state: ONLINE
scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
   mirror-0    ONLINE       0      0      0
      c0t1d0   ONLINE       0      0      0
      c1t1d0   ONLINE       0      0      0
errors: No known data errors
```

### Example 4-6 Removing a Mirrored Log Device

This example shows how to remove the log device `mirror-1` that was created in Adding a Mirrored Log Device. Note that if the log device is not redundant, then remove the device by referring to the device name, such as `c0t6d0`.

```
$ zpool remove newpool mirror-1
$ zpool status newpool
  pool: newpool
 state: ONLINE
 scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
newpool        ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
      c0t4d0   ONLINE       0      0      0
      c0t5d0   ONLINE       0      0      0

errors: No known data errors
```

**Example 4-7 Removing Cache Devices**

This example shows how to remove the cache device that was created in Adding Cache Devices.

```
$ zpool remove system1 c2t5d0 c2t8d0
$ zpool status system1
pool: system1
state: ONLINE
scrub: none requested
config:

NAME           STATE     READ  WRITE  CKSUM
system1        ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
      c2t0d0   ONLINE       0      0      0
      c2t1d0   ONLINE       0      0      0
      c2t3d0   ONLINE       0      0      0

errors: No known data errors
```

# Attaching and Detaching Devices in a Storage Pool

To add a new device to an existing virtual device, use the following command:

```
$ zpool attach pool existing-device new-device
```

You can use the `zpool detach` command to detach a device provided one of the following conditions applies:

- The device belongs to a mirrored pool configuration.
- In a RAID-Z configuration, the detached device is replaced by another physical device or by a spare.

Outside of these conditions, detaching a device generates an error similar to the following:

```
cannot detach c1t2d0: only applicable to mirror and replacing vdevs
```

The following examples show how to apply `zfs attach` commands.

**Example 4-8 Converting a Two-Way Mirrored Storage Pool to a Three-Way Mirrored Storage Pool**

In this example, `mpool` is an existing two-way mirror pool. It is converted into a three-way mirror pool by attaching `c2t1d0`, the new device, to the existing device `c1t1d0`. The newly attached device is immediately resilvered.

```
$ zpool attach mpool c1t1d0 c2t1d0
$ zpool status mpool
pool: mpool
state: ONLINE
scrub: resilver completed after 0h0m with 0 errors on Fri Jan  8 12:59:20 2010
config:

NAME           STATE     READ  WRITE  CKSUM
mpool          ONLINE       0      0      0
   mirror-0    ONLINE       0      0      0
      c0t1d0   ONLINE       0      0      0
      c1t1d0   ONLINE       0      0      0
      c2t1d0   ONLINE       0      0      0  592K resilveredAttached device creates a 3-
way mirror pool
```

```
errors: No known data errors
```

**Example 4-9 Converting a Nonredundant Storage Pool to a Mirrored Storage Pool**

The `zpool attach` command also enables you to convert a storage pool or a log device from a nonredundant to a redundant configuration.

The following example shows the status of the nonredundant pool `system1` before and after it is converted into a redundant pool.

```
$ zpool status system1
pool: system1
state: ONLINE
scrub: none requested
config:
NAME           STATE      READ  WRITE  CKSUM
system1        ONLINE        0      0      0
     c0t1d0    ONLINE        0      0      0

errors: No known data errors
$ zpool attach system1 c0t1d0 c1t1d0
$ zpool status system1
pool: system1
state: ONLINE
scrub: resilver completed after 0h0m with 0 errors on Fri Jan  8 14:28:23 2010
config:

NAME           STATE     READ  WRITE  CKSUM
system1        ONLINE       0      0      0Pool becomes mirrored
   mirror-0    ONLINE       0      0      0
      c0t1d0   ONLINE       0      0      0
      c1t1d0   ONLINE       0      0      0  73.5K resilvered

errors: No known data errors
```

# Splitting a Mirrored Storage Pool to Create a New Pool

You can quickly clone a mirrored ZFS storage pool by using the `zpool split` command. The new pool will have identical contents to the original mirrored ZFS storage pool. You can then import the new pool either to the same system or to another system. For more information about importing pools, see Importing ZFS Storage Pools.

To split a pool, use the following command:

```
$ zpool split pool new-pool [device]
```

Unless you specify the device, the `zpool split` command by default detaches the last disk of the pool's virtual device for the newly created pool. If a pool has multiple top-level virtual devices, the command detaches a disk from each virtual device to create a new pool out of those disks.

Splitting a pool applies only to mirrored configurations. You cannot split a RAID-Z configured pool or a nonredundant pool.

If you split a pool that has only a single top-level device consisting of three disks, the new pool created out of the third disk is nonredundant. The remaining pool retains data redundancy with its two remaining disks. To convert the new pool into a redundant configuration, attach a new device to the pool.

For more procedures and examples about splitting a ZFS pool with the `zpool split` command, log in to your account at My Oracle Support (https://support.oracle.com) and see "How to Use 'zpool split' to Split an rpool (Doc ID 1637715.1)".

Ensure the following before splitting a mirrored pool:

- Data and application operations are quiesced.
- No resilvering is in progress.
- Your hardware is configured correctly. For related information about confirming your hardware's cache flush settings, see General System Practices.

Before the actual split operation occurs, data in memory is flushed to the mirrored disks. After the data is flushed, the disk is detached from the pool and given a new pool GUID so that the pool can be imported on the same system on which it was split.

If the pool to be split has non-default file system mount points and the new pool is created on the same system, then you must use the `zpool split -R` command to identify an alternate root directory for the new pool so that any existing mount points do not conflict. For example:

```
$ zpool split -R /system2 system1 system2
```

If you don't use the `zpool split -R` command and you can see that mount points conflict when you attempt to import the new pool, import the new pool with the `-R` option. If the new pool is created on a different system, then specifying an alternate root directory is not necessary unless mount point conflicts occur.

**Example 4-10 Splitting a Mirrored ZFS Pool**

In this example, a mirrored storage pool called `poolA` with three disks is split. The two resulting pools are the mirrored pool `poolA` with two disks and the new pool `poolB` with one disk.

```
$ zpool status poolA
  pool: poolA
 state: ONLINE
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        poolA       ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            c0t0d0  ONLINE       0     0     0
            c0t1d0  ONLINE       0     0     0
            c0t2d0  ONLINE       0     0     0

errors: No known data errors
$ zpool split poolA poolB
$ zpool import luna
$ zpool status poolA poolB
  pool: luna
 state: ONLINE
  scan: none requested
config:

        NAME      STATE     READ WRITE CKSUM
        poolB     ONLINE       0     0     0
          c0t2d0  ONLINE       0     0     0

errors: No known data errors

  pool: poolA
 state: ONLINE
```

```
  scan: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        poolA       ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            c0t0d0  ONLINE       0     0     0
            c0t1d0  ONLINE       0     0     0

errors: No known data errors
```

With the new configuration, you can perform other operations. For example, you can import `poolB` on another system for backup purposes. After the backup is complete, you can destroy `poolB` and reattach the disk to `poolA`.

# Taking Devices in a Storage Pool Offline or Returning Online

When a device in a storage pool becomes permanently unreliable or non-functional, you can take the device offline with the following command:

```
$ zpool offline [option] pool device
```

where the name of *device* can either be the short name or the full path.

When you take a device offline, its `OFFLINE` state becomes persistent. For a nonpersistent `OFFLINE` state, use the `-t` option, which takes the device temporarily offline. When the system is rebooted, the device is automatically restored to the `ONLINE` state.

> **Caution:**
>
> Do not take devices offline such that the pool itself becomes unavailable. For example, you cannot take offline two devices in a `raidz1` configuration, nor can you take offline a top-level virtual device. The following error message would be displayed:
>
> ```
> cannot offline c0t5000C500335F95E3d0: no valid replicas
> ```

The `OFFLINE` state does not mean that the device is detached from the pool. Therefore, you cannot use that device for another pool. Otherwise, an error message is generated similar to the following example:

```
device is part of exported or potentially active ZFS pool. Please see zpool(8)
```

To use the device for another pool, first restore the device to the `ONLINE` state, and then destroy the pool to which the device belongs.

If you do not want to destroy the pool, replace the offline device with a comparable device. The replaced device then becomes available for a different pool.

> **Note:**
>
> You do not need to take devices offline to replace them.

To return a device online, use the following command:

```
$ zpool online [option] pool device
```

Any data that has been written to the pool is resynchronized with the newly available device.

If you try to bring online a device whose state is `UNAVAIL`, a message about a faulted device is displayed, similar to the following example:

```
warning: device 'device' onlined, but remains in faulted state
use 'zpool clear' to restore a faulted device
```

Messages about faulted device might also be displayed on the console or written to the `/var/adm/messages` file.

For more information about replacing a faulted device, see Resolving a Missing or Removed Device.

To expand a LUN, use the `zpool online -e` command. By default, a LUN that is added to a pool is not expanded to its full size unless the `autoexpand` pool property is enabled. If the property is disabled, use the command to expand the LUN automatically. You can run the command regardless of whether the LUN is offline or already online.

# Clearing Storage Pool Device Errors

Pool device failures, such as temporarily losing connectivity, can cause errors that are also reported in a `zpool status` output. To clear such errors, use the following command:

```
$ zpool clear pool [devices]
```

If devices are specified, the command clears only those errors that are associated with the devices. Otherwise, the command clears all device errors within the pool.

For more information about clearing `zpool` errors, see Clearing Transient or Persistent Device Errors.

# Replacing Devices in a Storage Pool

You can replace a device in a storage pool by using the `zpool replace` command.

```
$ zpool replace pool replaced-device [new-device]
```

If you are installing a device's replacement on the same location in a redundant pool, you might only need to identify the replaced device. On some hardware, ZFS recognizes the new device on the same location. However, if you install the replacement on a different location, you must specify both the replaced device and the new device.

The automatic detection of replaced devices is hardware-dependent and might not be supported on all platforms. Furthermore, some hardware types support the `autoreplace` pool property. If this property is enabled, then a device's replacement on the same location is automatically formatted and replaced. Running the `zpool replace` command is unnecessary.

Note the following guidelines:

- A hot spare device, if available, automatically replaces a device that is removed while the system is running. After a failed disk is replaced, you might need to detach the spare by using the `zpool detach` command. For information about detaching a hot spare, see Activating and Deactivating Hot Spares in Your Storage Pool.

- A device that is removed and then reinserted is automatically brought online. In this case, no replacement occurred. The replacement hot spare device is automatically removed after the reinserted device is brought back online.

When you replace a device with one that has a larger capacity, the new device is not automatically expanded to its full size after you add it to the pool. The `autoexpand` pool property determines the automatic expansion of a replacement LUN. By default, this property is disabled. You can enable it before or after the larger LUN is added to the pool.

On some systems with SATA disks, you must unconfigure a disk before you can take it offline. If you are replacing a disk in the same slot position on this system, then you can just run the `zpool replace` command as described in Replacing Devices in a Mirrored Poolthe first example in this section. For an example of replacing a SATA disk, see Replacing a SATA Disk in a ZFS Storage Pool.

Because of the resilvering of data onto new disks, replacing disks is time-consuming. Between disk replacements, run the `zpool scrub` command to ensure that the replacement devices are operational and that the data is written correctly.

For more information about replacing devices, see Resolving a Missing or Removed Device and Replacing or Repairing a Damaged Device.

## How to Replace a Device in a Storage Pool

1. **If necessary, switch the device to the OFFLINE state.**

   ```
   $ zpool offline pool device
   ```

2. **Physically replace the device with a new device.**

   In the case of redundant storage pools, ensure that the replacement device is equal to or larger than the smallest disk in the pool.

3. **Run the format command.**

   Check the following in the output:

   - Ensure that the new device is listed.
   - Check whether the replacement device is marked as `WWN` to verify that the device ID has changed.

4. **Replace the device in the pool.**

   If the new device has a new ID, include the ID in the command.

   ```
   $ zpool replaced pool replaced-device [new-device-ID]
   ```

   > **Note:**
   >
   > If you are replacing multiple devices, make sure that each device is fully resilvered before you replace the next device.

5. **If necessary, bring the device online.**

   ```
   $ zpool online pool new-device
   ```

6. **If faulted device errors are reported, perform FMA procedures.**

   a. **Run the command fmadm faulty.**

   b. **From the Affects: section of the output, identify the pool name and the GUID of the virtual device.**

c. **Run the following command and provide the information from the previous step.**

```
$ fmadm repaired zfs://pool=name/vdev=guid
```

**Example 4-11 Replacing Devices in a Mirrored Pool**

In this example, two 16GB disks in the pool `system1` are replaced with two 72GB disks. The `autoexpand` property is enabled after the disk replacements to expand the full disk sizes.

```
$ zpool status system1
  pool: system1
 state: ONLINE
 scrub: none requested
config:

        NAME          STATE     READ WRITE CKSUM
        system1       ONLINE       0     0     0
          mirror      ONLINE       0     0     0
            c1t16d0   ONLINE       0     0     0
            c1t17d0   ONLINE       0     0     0

$ zpool list system1
NAME      SIZE   ALLOC   FREE    CAP  HEALTH  ALTROOT
system1  16.8G   76.5K  16.7G     0%  ONLINE  -
$ zpool replaced system1 c1t16d0 c1t1d0
$ zpool replaced system1 c1t17d0 c1t2d0
$ zpool list system1
NAME      SIZE   ALLOC   FREE    CAP  HEALTH  ALTROOT
system1  16.8G   88.5K  16.7G     0%  ONLINE  -
$ zpool set autoexpand=on system1
$ zpool list system1
NAME      SIZE   ALLOC   FREE    CAP  HEALTH  ALTROOT
system1  68.2G    117K  68.2G     0%  ONLINE  -
```

# Working With Hot Spares in Storage Pools

The hot spares feature enables you to identify disks that could be used to replace a failed or faulted device in a storage pool. A hot spare device is inactive in a pool until the spare replaces the failed device.

## Designating Hot Spares in a Storage Pool

Devices can be designated as hot spares in the following ways:

- When the pool is created.

  ```
  $ zpool create pool keyword devices spare devices
  ```

- After the pool is created.

  ```
  $ zpool add pool spare devices
  ```

To remove a hot spare, use the following command:

```
$ zpool remove pool spare-device
```

> **Note:**
>
> You cannot remove a hot spare that is currently being used by the pool.

A hot spare device must be equal to or larger than the size of the largest disk in the pool. Otherwise, the smaller spare device can still be designated as a hot spare. However, when that device is activated to replace a failed device, the operation fails with the following error message:

```
cannot replace disk3 with disk4: device is too small
```

Do not share a spare across multiple pools or multiple systems even if the device is visible for access by these systems. You can configure a disk to be shared among several pools provided that only a single system must control all of these pools. However, this practice is risky. For example, if pool A that is using the shared spare is exported, pool B could unknowingly use the spare while pool A is exported. When pool A is imported, data corruption could occur because both pools are using the same disk.

## Activating and Deactivating Hot Spares in Your Storage Pool

You activate hot spares in the following ways:

- Manual replacement – Run the `zpool replace` command to replace a failed device. When a new device is inserted to replace the failed disk, you activate the new device by detaching the spare.
- Automatic replacement – An FMA agent detects a fault, determines spare availability, and automatically replaces the faulted device. A hot spare also replaces a device in the `UNAVAIL` state.

  If you set the `autoreplace` pool property to `on`, the spare is automatically detached and returned to the spare pool when the new device is inserted and the online operation completes.

To deactivate a hot spare, perform one of the following actions:

- Remove the hot spare from the storage pool.
- Detach the hot spare after physically replacing a failed disk. See Detaching a Hot Spare After the Failed Disk Is Replaced.
- Swap in another hot spare either temporarily or permanently. See Detaching a Failed Disk and Using the Hot Spare.

**Example 4-12 Detaching a Hot Spare After the Failed Disk Is Replaced**

This example assume the following configuration:

- In `system1`'s `mirror-1` configuration, disk `c0t5000C500335BA8C3d0` has failed. The following partial output shows the status of `mirror-1`:

```
$ zpool status system1
.
  mirror-1                  DEGRADED     0     0     0
    c0t5000C500335BD117d0   ONLINE       0     0     0
    c0t5000C500335BA8C3d0   UNAVAIL      0     0     0Failed disk
```

- The pool's spare `c0t5000C500335E106Bd0` is automatically activated to replace the failed disk.
- You physically replace the failed disk with a new device `c0t5000C500335DC60Fd0`.

The example begins with reconfiguring the pool with the new device. First, you run `zpool replace` to inform ZFS about the removed device. Then, if necessary, you run `zpool detach` to deactivate the spare and return it to the spare pool. The example ends with displaying the

status of the new configuration and performing the appropriate FMA steps for fault devices, as shown in Step 6 of How to Replace a Device in a Storage Pool.

```
$ zpool replace system1 c0t5000C500335BA8C3d0
$ zpool detach system1 c0t5000C500335E106Bd0
$ zpool status system1
.
.
  mirror-1                  ONLINE       0     0     0
    c0t5000C500335BD117d0   ONLINE       0     0     0
    c0t5000C500335DC60Fd0   ONLINE       0     0     0Replacement device
  spares
    c0t5000C500335E106Bd0    AVAIL                   Deactivated spare

$ fmadm faulty
$ fmadm repaired zfs://pool=name/vdev=guid
```

### Example 4-13 Detaching a Failed Disk and Using the Hot Spare

Instead of a new replacement device, you can use the spare device as a permanent replacement instead. In this case, you simply detach the failed disk. If the failed disk is subsequently repaired, then you can add it to the pool as a newly designated spare.

This example uses the same assumptions as Detaching a Hot Spare After the Failed Disk Is Replaced.

- The `mirror-1` configuration of the pool `system1` is in a degraded state.

  ```
  $ zpool status system1
  .
    mirror-1                  DEGRADED     0     0     0
      c0t5000C500335BD117d0   ONLINE       0     0     0
      c0t5000C500335BA8C3d0   UNAVAIL      0     0     0Failed disk
  ```

- The pool's spare `c0t5000C500335E106Bd0` is automatically activated to replace the failed disk.

The example begins with detaching the failed disk that has been replaced by the spare.

```
$ zpool detach system1 c0t5000C500335BA8C3d0
$ zpool status system1
.
.
  mirror-1                  ONLINE       0     0     0
    c0t5000C500335BD117d0   ONLINE       0     0     0
    c0t5000C500335E106Bd0   ONLINE       0     0     0Spare replaces failed disk

errors: No known data errors
```

Subsequently, you add the repaired disk back to the pool as the spare device. You complete the procedure by performing the appropriate FMA steps for fault devices.

```
$ zpool add system1 spare c0t5000C500335BA8C3d0
$ zpool status system1
.
.
  mirror-1                  ONLINE       0     0     0
    c0t5000C500335BD117d0   ONLINE       0     0     0
    c0t5000C500335E106Bd0   ONLINE       0     0     0Former spare
  spares
    c0t5000C500335BA8C3d0    AVAIL                   Repaired disk as spare

errors: No known data errors
```

```
$ fmadm faulty
$ fmadm repaired zfs://pool=name/vdev=guid
```

5

# Managing Oracle Solaris ZFS Storage Pools

This chapter describes how to administer storage pools in Oracle Solaris ZFS. It has the following sections:



## Managing ZFS Storage Pool Properties

To manage ZFS pool properties, you use the following commands:

- `zpool get all` *pool* – Lists all the properties of the pool with their corresponding values.
- `zpool get` *property pool* – Lists the specified property of the pool with its corresponding value.
- `zpool set` *property=value pool* – Assigns a value to the pool's specified property.

If you attempt to set a pool property on a pool that is full, a message similar to the following is displayed:

```
$ zpool set autoreplace=on system1
cannot set property for 'system1': out of space
```

For information about preventing pool space capacity problems, see Recommended Oracle Solaris ZFS Practices.

**Table 5-1 ZFS Pool Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| `allocated` | String | N/A | Read-only value that identifies the amount of storage space within the pool that has been physically allocated. |
| `altroot` | String | `off` | Identifies an alternate root directory. If set, this directory is prepended to any mount points within the pool. This property can be used in the following situations: when you are examining an unknown pool, if the mount points cannot be trusted, or in an alternate boot environment where the typical paths are not valid. |
| `autoreplace` | Boolean | `off` | Controls automatic device replacement. If set to `off`, you must initiate device replacement using the `zpool replace` command. If set to `on`, any new device found in the same physical location as a device that previously belonged to the pool is automatically formatted and replaced. The property abbreviation is `replace`. |
| `bootfs` | Boolean | N/A | Identifies the default bootable file system for the root pool. This property is typically set by the installation programs. |

**Table 5-1 (Cont.) ZFS Pool Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| `cachefile` | String | N/A | Controls where pool configuration information is cached. All pools in the cache are automatically imported when the system boots. However, installation and clustering environments might require this information to be cached in a different location so that pools are not automatically imported. You can set this property to cache pool configuration information in a different location. This information can be imported later by using the `zpool import -c` command.<br>For most ZFS configurations, this property is not used. |
| `capacity` | Number | N/A | Read-only value that identifies the percentage of pool space used.<br>The property abbreviation is `cap`. |
| `clustered` | String | `off` | Provides support for global mounting of a ZFS file system in an Oracle Solaris Cluster environment. |
| `dedupditto` | String | N/A | Sets a threshold for the reference count for a deduped block. If the count goes above the threshold, another ditto copy of the block is stored automatically. |
| `dedupratio` | String | N/A | Read-only deduplication ratio achieved for a pool, expressed as a multiplier. |
| `delegation` | Boolean | `on` | Controls whether a nonprivileged user can be granted access permissions that are defined for a file system. For more information, see Oracle Solaris ZFS Delegated Administration. |
| `failmode` | String | `wait` | Controls the system behavior if a catastrophic pool failure occurs. This condition is typically a result of a loss of connectivity to the underlying storage device or devices or a failure of all devices within the pool. The behavior of such an event is determined by one of the following values:<br>• `wait` – Blocks all I/O requests to the pool until device connectivity is restored and the errors are cleared by using the `zpool clear` command. In this state, I/O operations to the pool are blocked but read operations might succeed. A pool remains in the `wait` state until the device issue is resolved.<br>• `continue` – Returns an EIO error to any new write I/O requests but allows reads to any of the remaining healthy devices. Any write requests that have yet to be committed to disk are blocked. After the device is reconnected or replaced, the errors must be cleared with the `zpool clear` command.<br>• `panic` – Prints a message to the console and generates a system crash dump. |
| `free` | String | N/A | Read-only value that identifies the number of blocks within the pool that are not allocated. |
| `guid` | String | N/A | Read-only property that identifies the unique identifier for the pool.<br>**Caution:** If you are using multiple pools, make sure that they all have unique GUIDs. Shared GUIDs among pools might result in unexpected behavior. |
| `health` | String | N/A | Read-only property that identifies the current health of the pool, as either `ONLINE`, `DEGRADED`, `SUSPENDED`, `REMOVED`, or `UNAVAIL`. |
| `listshares` | String | off | Controls whether share information in this pool is displayed with the `zfs list` command. The default value is `off`. |

**Table 5-1 (Cont.) ZFS Pool Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| `listsnapshots` | String | off | Controls whether snapshot information that is associated with this pool is displayed with the `zfs list` command. If this property is disabled, you can display snapshot information with the `zfs list -t snapshot` command. |
| `readonly` | Boolean | off | Identifies whether a pool can be modified. This property is enabled only when a pool is has been imported in read-only mode. If enabled, any synchronous data that exists only in the intent log will not be accessible until the pool is re-imported in read-write mode. |
| `size` | Number | N/A | Read-only property that identifies the total size of the storage pool. |
| `version` | Number | N/A | Identifies the current on-disk version of the pool. The preferred method of updating pools is with the `zpool upgrade` command, although you can use this property when you need a specific version for backward compatibility. You can set this property to any number between 1 and the current version reported by the `zpool upgrade -v` command. |

# Querying ZFS Storage Pool Status

The `zpool list` command provides several ways to request information regarding pool status. The information available generally falls into three categories: basic usage information, I/O statistics, and health status. This section discuses all three types of storage pool information.

## Displaying Information About ZFS Storage Pools

The `zpool list` command displays basic information about pools. You can use the command in the following ways:

- Without options: `zpool list [`*pool*`]`

  If you do not specify a pool, then information for all pools is displayed.
- With options: `zpool list` *options* `[`*arguments*`]`

## Displaying Information About All Storage Pools or a Specific Pool

The `zpool list [`*pool*`]` command displays the following pool information:

**NAME**
Name of the pool.

**SIZE**
Total size of the pool, equal to the sum of the sizes of all top-level virtual devices.

**ALLOC**
Amount of physical space allocated to all datasets and internal metadata. Note that this amount differs from the amount of disk space as reported at the file system level.

**FREE**
Amount of unallocated space in the pool.

**CAP (CAPACITY)**
Amount of disk space used, expressed as a percentage of the total disk space.

**HEALTH**
Current health status of the pool.
For more information about pool health, see Determining the Health Status of ZFS Storage Pools.

**ALTROOT**
Alternate root of the pool, if one exists.
For more information about alternate root pools, see Using a ZFS Pool With an Alternate Root Location.

The following example shows sample `zpool list` command output:

```
$ zpool list
NAME                    SIZE    ALLOC    FREE    CAP  HEALTH     ALTROOT
syspool1                80.0G   22.3G   47.7G    28%  ONLINE     -
syspool2                 1.2T    384G    816G    32%  ONLINE     -
```

To obtain statistics for a specific pool, specify the pool name with the command.

## Displaying Specific Storage Pool Statistics

You can select the specific pool information to be displayed by issuing options and arguments with the `zpool list` command.

The `-o` option enables you to filter which columns are displayed. The following example shows how to list only the name and size of each pool:

```
$ zpool list -o name,size
NAME                     SIZE
syspool1                80.0G
syspool2                 1.2T
```

You can use the `zpool list` command as part of a shell script by issuing the combined `-Ho` options. The `-H` option suppresses display of column headings and instead displays tab-separated pool information. For example:

```
$ zpool list -Ho name,size
syspool1   80.0G
syspool2  1.2T
```

The `-T` option enables you to gather time-stamped statistics about the pools. Use the following syntax:

```
$ zpool list -T d interval [count]
```

**d**
Specifies to use the standard date format when displaying the date.

***interval***
Specifies the interval in seconds between which information is displayed.

**count**
Specifies the number of times to report the information. If you do not specify *count* then the information is continuously refreshed at the specified interval until you press Ctl-C.

The following example displays pool information twice, with a 3-second gap between the reports. The output uses the standard format to display the date.

```
$ zpool list -T d 3 2
Tue Nov  2 10:36:11 MDT 2010
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
pool   33.8G  83.5K  33.7G     0%  1.00x  ONLINE  -
rpool  33.8G  12.2G  21.5G    36%  1.00x  ONLINE  -
Tue Nov  2 10:36:14 MDT 2010
pool   33.8G  83.5K  33.7G     0%  1.00x  ONLINE  -
rpool  33.8G  12.2G  21.5G    36%  1.00x  ONLINE  -
```

## Displaying Pool Devices by Physical Locations

Use the `zpool status -l` command to display information about the physical location of pool devices. Reviewing the physical location information is helpful when you need to physically remove or replace a disk.

In addition, you can use the `fmadm add-alias` command to include a disk alias name that helps you identify the physical location of disks in your environment. For example:

```
$ fmadm add-alias SUN-Storage-J4400.1002QCQ015 Lab10Rack5disk

$ zpool status -l system1
  pool: system1
 state: ONLINE
  scan: scrub repaired 0 in 0h0m with 0 errors on Fri Aug  3 16:00:35 2012
config:

        NAME                                          STATE     READ WRITE CKSUM
        system1                                       ONLINE       0     0     0
          mirror-0                                    ONLINE       0     0     0
            /dev/chassis/Lab10Rack5.../DISK_02/disk   ONLINE       0     0     0
            /dev/chassis/Lab10Rack5.../DISK_20/disk   ONLINE       0     0     0
          mirror-1                                    ONLINE       0     0     0
            /dev/chassis/Lab10Rack5.../DISK_22/disk   ONLINE       0     0     0
            /dev/chassis/Lab10Rack5.../DISK_14/disk   ONLINE       0     0     0
          mirror-2                                    ONLINE       0     0     0
            /dev/chassis/Lab10Rack5.../DISK_10/disk   ONLINE       0     0     0
            /dev/chassis/Lab10Rack5.../DISK_16/disk   ONLINE       0     0     0
.
.
.
        spares
          /dev/chassis/Lab10Rack5.../DISK_17/disk     AVAIL
          /dev/chassis/Lab10Rack5.../DISK_12/disk     AVAIL

errors: No known data errors
```

## Displaying ZFS Storage Pool Command History

Use the `zpool history` command to display the log of `zfs` and `zpool` command use. The log records when these commands were successfully used to modify pool state information or to troubleshoot an error condition.

Note the following information about the history log:

- You cannot disable the log. The log is saved persistently on disk and is preserved across system reboots.
- The log is implemented as a ring buffer. The minimum size is 128 KB. The maximum size is 32 MB.

- For smaller pools, the maximum size is capped at 1 percent of the pool size, where the size is determined at pool creation time.
- Because the log requires no administration, you do not need to tune the log size or its location.

The following example shows the `zfs` and `zpool` command history on the pool `system1`.

```
$ zpool history system1
2012-01-25.16:35:32 zpool create -f system1 mirror c3t1d0 c3t2d0 spare c3t3d0
2012-02-17.13:04:10 zfs create system1/test
2012-02-17.13:05:01 zfs snapshot -r system1/test@snap1
```

Use the `-l` option to display a long format that includes the user name, the host name, and the zone in which the operation was performed. For example:

```
$ zpool history -l system1
History for 'system1':
2012-01-25.16:35:32 zpool create -f system1 mirror c3t1d0 c3t2d0 spare c3t3d0
[user root on host1:global]
2012-02-17.13:04:10 zfs create system1/test [user root on host1:global]
2012-02-17.13:05:01 zfs snapshot -r system1/test@snap1 [user root on host1:global]
```

Use the `-i` option to display internal event information that can be used for diagnostic purposes. For example:

```
$ zpool history -i system1
History for 'system1':
2012-01-25.16:35:32 zpool create -f system1 mirror c3t1d0 c3t2d0 spare c3t3d0
2012-01-25.16:35:32 [internal pool create txg:5] pool spa 33; zfs spa 33; zpl 5;
uts host1 5.11 11.1 sun4v
2012-02-17.13:04:10 zfs create system1/test
2012-02-17.13:04:10 [internal property set txg:66094] $share2=2 dataset = 34
2012-02-17.13:04:31 [internal snapshot txg:66095] dataset = 56
2012-02-17.13:05:01 zfs snapshot -r system1/test@snap1
2012-02-17.13:08:00 [internal user hold txg:66102] <.send-4736-1> temp = 1 ...
```

# Viewing I/O Statistics for ZFS Storage Pools

To request I/O statistics for a pool or specific virtual devices, use the `zpool iostat` command. Similar to the `iostat` command, this command can display a static snapshot of all I/O activity, as well as updated statistics for every specified interval. The following statistics are reported:

**`alloc capacity`**
The amount of data currently stored in the pool or device. This amount differs from the amount of disk space available to actual file systems by a small margin due to internal implementation details.

**`free capacity`**
The amount of disk space available in the pool or device. Like the `used` statistic, this amount differs from the amount of disk space available to datasets by a small margin.

**`read operations`**
The number of read I/O operations sent to the pool or device, including metadata requests.

**`write operations`**
The number of write I/O operations sent to the pool or device.

**read bandwidth**
The bandwidth of all read operations (including metadata), expressed as units per second.

**write bandwidth**
The bandwidth of all write operations, expressed as units per second.

## Listing Pool-Wide I/O Statistics

When issued with no options, the `zpool iostat` command displays the accumulated statistics since boot for all pools on the system. For example:

```
$ zpool iostat
capacity     operations    bandwidth
pool        alloc   free   read  write   read  write
----------  -----  -----  -----  -----  -----  -----
rpool       6.05G  61.9G      0      0    786    107
system1     31.3G  36.7G      4      1   296K  86.1K
----------  -----  -----  -----  -----  -----  -----
```

Because these statistics are cumulative since boot, bandwidth might appear low if the pool is relatively idle. You can request a more accurate view of current bandwidth usage by specifying an interval. For example:

```
$ zpool iostat system1 2
capacity     operations    bandwidth
pool           alloc   free   read  write   read  write
----------     -----   -----  ----  -----  -----  -----
system1        18.5G  49.5G      0    187      0  23.3M
system1        18.5G  49.5G      0    464      0  57.7M
system1        18.5G  49.5G      0    457      0  56.6M
system1        18.8G  49.2G      0    435      0  51.3M
```

In this example, the command displays usage statistics for the pool `system1` every two seconds until you press Control-C. Alternately, you can specify an additional `count` argument, which causes the command to terminate after the specified number of iterations.

For example, `zpool iostat 2 3` would print a summary every two seconds for three iterations, for a total of six seconds.

## Listing Virtual Device I/O Statistics

The `zpool iostat -v` command can display I/O statistics for virtual devices. Use this command to identify abnormally slow devices or to observe the distribution of I/O generated by ZFS. See the following three examples. The last two examples display a multigroup configuration.

```
$ zpool iostat -v tank
                           capacity     operations    bandwidth
pool                     alloc   free   read  write   read  write
-----------------------  -----  -----  -----  -----  -----  -----
tank                     2.69G  1.81T      0     29    252  14.2M
  c0t5000C5001032271Bd0  1.34G   927G      0     14    130  7.09M
  c0t5000C50010349387d0  1.34G   927G      0     14    122  7.09M
-----------------------  -----  -----  -----  -----  -----  -----
```

```
$ zpool iostat -v tank
                             capacity     operations    bandwidth
pool                       alloc   free   read  write   read  write
-------------------------  -----  -----  -----  -----  -----  -----
tank                        810M  1.81T      0    390    536  32.1M
```

```
  mirror-0                  405M   928G      0    194    232  16.1M
    c0t5000C5001032271Bd0      -      -      0     37  1.07K  16.2M
    c0t5000C50010349387d0      -      -      0     38    858  16.1M
  mirror-1                  405M   928G      0    195    304  16.1M
    c0t5000C5001033963Fd0      -      -      0     37  1.14K  16.2M
    c0t5000C5001033024Fd0      -      -      0     38    858  16.2M
------------------------  -----  -----  -----  -----  -----  -----
```

```
$ zpool iostat -v tank
                            capacity     operations    bandwidth
pool                      alloc   free   read  write   read  write
------------------------  -----  -----  -----  -----  -----  -----
tank                       258M  5.44T      0    321    876  31.5M
  raidz1-0                 128M  2.72T      0    160     29  15.9M
    c0t5000C5001032271Bd0     -      -      0     33  1.40K  8.07M
    c0t5000C50010349387d0     -      -      0     30  1.37K  8.07M
    c0t5000C5001033963Fd0     -      -      0     30  1.37K  8.07M
  raidz1-1                 130M  2.72T      0    160    847  15.5M
    c0t5000C5001033024Fd0     -      -      1     34  2.20K  8.10M
    c0t5000C500103C9817d0     -      -      0     34  1.37K  7.87M
    c0t5000C50010324F67d0     -      -      0     34  1.37K  8.10M
------------------------  -----  -----  -----  -----  -----  -----
```

The `zpool iostat -v` command provides specific information for each level of the pool configuration:

- Pool level shows the sum of the group level data.
- Group level shows the compiled data of the mirror or raidz configuration.
- Leaf level shows information for each physical disk.

Note two important points when viewing I/O statistics for virtual devices:

- Statistics on disk space use are available only for top-level virtual devices. The way in which disk space is allocated among mirror and RAID-Z virtual devices is particular to the implementation and not easily expressed as a single number.
- The numbers might not add up exactly as you would expect. In particular, operations across RAID-Z and mirrored devices will not be exactly equal. This difference is particularly noticeable immediately after a pool is created because a significant amount of I/O is done directly to the disks as part of pool creation, which is not accounted for at the mirror level. Over time, these numbers gradually equalize. However, broken, unresponsive, or offline devices can affect this symmetry as well.

You can use `interval` and `count` when examining virtual device statistics.

You can also display physical location information about the pool's virtual devices. The following example shows sample output that has been truncated:

```
$ zpool iostat -lv
               capacity     operations    bandwidth
pool        alloc   free   read  write   read  write
----------  -----  -----  -----  -----  -----  -----
export      2.39T  2.14T     13     27  42.7K   300K
  mirror     490G   438G      2      5  8.53K  60.3K
    /dev/chassis/lab10rack15/SCSI_Device__2/disk      -   -    1    0  4.47K  60.3K
    /dev/chassis/lab10rack15/SCSI_Device__3/disk      -   -    1    0  4.45K  60.3K
  mirror     490G   438G      2      5  8.62K  59.9K
    /dev/chassis/lab10rack15/SCSI_Device__4/disk      -   -    1    0  4.52K  59.9K
    /dev/chassis/lab10rack15/SCSI_Device__5/disk      -   -    1    0  4.48K  59.9K
```

# Determining the Health Status of ZFS Storage Pools

You can display pool and device health by using the `zpool status` command. In addition, the `fmd` command also reports potential pool and device failures on the system console, and the `/var/adm/messages` file.

This section describes only how to determine pool and device health. For data recovery from unhealthy pools, see Oracle Solaris ZFS Troubleshooting and Pool Recovery.

A pool's health status is described by one of four states:

**DEGRADED**
A pool with one or more failed devices whose data is still available due to a redundant configuration.

**ONLINE**
A pool that has all devices operating normally.

**SUSPENDED**
A pool that is waiting for device connectivity to be restored. A `SUSPENDED` pool remains in the wait state until the device issue is resolved.

**UNAVAIL**
A pool with corrupted metadata, or one or more unavailable devices, and insufficient replicas to continue functioning.

Each pool device can fall into one of the following states:

**DEGRADED**
The virtual device has experienced a failure but can still function. This state is most common when a mirror or RAID-Z device has lost one or more constituent devices. The fault tolerance of the pool might be compromised because a subsequent fault in another device might be unrecoverable.

**OFFLINE**
The device has been explicitly taken offline by the administrator.

**ONLINE**
The device or virtual device is in normal working order even though some transient errors might still occur.

**REMOVED**
The device was physically removed while the system was running. Device removal detection is hardware-dependent and might not be supported on all platforms.

**UNAVAIL**
The device or virtual device cannot be opened. In some cases, pools with `UNAVAIL` devices appear in `DEGRADED` mode. If a top-level virtual device is `UNAVAIL`, then nothing in the pool can be accessed.

The health of a pool is determined from the health of all its top-level virtual devices. If all virtual devices are `ONLINE`, then the pool is also `ONLINE`. If any one of the virtual devices is `DEGRADED` or `UNAVAIL`, then the pool is also `DEGRADED`. If a top-level virtual device is `UNAVAIL` or `OFFLINE`, then the pool is also `UNAVAIL` or `SUSPENDED`. A pool in the `UNAVAIL` or `SUSPENDED` state is completely inaccessible. No data can be recovered until the necessary devices are attached or

repaired. A pool in the DEGRADED state continues to run but you might not achieve the same level of data redundancy or data throughput than if the pool were online.

The zpool status command also displays the state of resilver and scrub operations as follows:

- Resilver or scrub operations are in progress.
- Resilver or scrub operations have been completed.

  Resilver and scrub completion messages persist across system reboots.
- Operations have been canceled.

## Storage Pool Health Status

You can review pool health status by using one of the following zpool status command options:

- zpool status -x [*pool*] – Displays only the status pools that have errors or are otherwise unavailable.
- zpool status -v [*pool*] – Generates verbose output providing detailed information about the pools and their devices.

  You should investigate any pool that is not in the ONLINE state for potential problems.

The following example shows how to generate a verbose status report about the pool system1.

```
$ zpool status -v system1
  pool: system1
 state: DEGRADED
status: One or more devices are unavailable in response to persistent errors.
        Sufficient replicas exist for the pool to continue functioning in a
        degraded state.
action: Determine if the device needs to be replaced, and clear the errors
        using 'zpool clear' or 'fmadm repaired', or replace the device
        with 'zpool replace'.
  scan: scrub repaired 0 in 0h0m with 0 errors on Wed Jun 20 15:38:08 2012
config:

        NAME                      STATE     READ WRITE CKSUM
        system1                   DEGRADED     0     0     0
          mirror-0                DEGRADED     0     0     0
            c0t5000C500335F95E3d0 ONLINE       0     0     0
            c0t5000C500335F907Fd0 UNAVAIL      0     0     0
          mirror-1                ONLINE       0     0     0
            c0t5000C500335BD117d0 ONLINE       0     0     0
            c0t5000C500335DC60Fd0 ONLINE       0     0     0

device details:

        c0t5000C500335F907Fd0    UNAVAIL          cannot open
        status: ZFS detected errors on this device.
                The device was missing.
           see: URL to My Oracle Support knowledge article for recovery


errors: No known data errors
```

The READ and WRITE columns provide a count of I/O errors that occurred on the device, while the CKSUM column provides a count of uncorrectable checksum errors that occurred on the device. Both error counts indicate a potential device failure for which some corrective action is

needed. If non-zero errors are reported for a top-level virtual device, portions of your data might have become inaccessible.

The output identifies problems as well as possible causes for the pool's current state. The output also includes a link to a knowledge article for up-to-date information about the best way to recover from the problem. From the output, you can determine which device is damaged and how to repair the pool.

For more information about diagnosing and repairing `UNAVAIL` pools and data, see Oracle Solaris ZFS Troubleshooting and Pool Recovery.

## Gathering ZFS Storage Pool Status Information

You can use the `zpool status` interval and count options to gather statistics over a period of time. In addition, you can display a time stamp by using the `-T` option. For example:

```
$ zpool status -T d 3 2
Wed Jun 20 16:10:09 MDT 2012
  pool: pond
 state: ONLINE
  scan: resilvered 9.50K in 0h0m with 0 errors on Wed Jun 20 16:07:34 2012
config:

        NAME                       STATE     READ WRITE CKSUM
        pond                       ONLINE       0     0     0
          mirror-0                 ONLINE       0     0     0
            c0t5000C500335F95E3d0  ONLINE       0     0     0
            c0t5000C500335F907Fd0  ONLINE       0     0     0
          mirror-1                 ONLINE       0     0     0
            c0t5000C500335BD117d0  ONLINE       0     0     0
            c0t5000C500335DC60Fd0  ONLINE       0     0     0

errors: No known data errors

  pool: rpool
 state: ONLINE
  scan: scrub repaired 0 in 0h11m with 0 errors on Wed Jun 20 15:08:23 2012
config:

        NAME                         STATE     READ WRITE CKSUM
        rpool                        ONLINE       0     0     0
          mirror-0                   ONLINE       0     0     0
            c0t5000C500335BA8C3d0s0  ONLINE       0     0     0
            c0t5000C500335FC3E7d0s0  ONLINE       0     0     0

errors: No known data errors
Wed Jun 20 16:10:12 MDT 2012

  pool: pond
 state: ONLINE
  scan: resilvered 9.50K in 0h0m with 0 errors on Wed Jun 20 16:07:34 2012
config:

        NAME                       STATE     READ WRITE CKSUM
        pond                       ONLINE       0     0     0
          mirror-0                 ONLINE       0     0     0
            c0t5000C500335F95E3d0  ONLINE       0     0     0
            c0t5000C500335F907Fd0  ONLINE       0     0     0
          mirror-1                 ONLINE       0     0     0
            c0t5000C500335BD117d0  ONLINE       0     0     0
            c0t5000C500335DC60Fd0  ONLINE       0     0     0
```

```
errors: No known data errors

  pool: rpool
 state: ONLINE
  scan: scrub repaired 0 in 0h11m with 0 errors on Wed Jun 20 15:08:23 2012
config:

        NAME                          STATE     READ WRITE CKSUM
        rpool                         ONLINE       0     0     0
          mirror-0                    ONLINE       0     0     0
            c0t5000C500335BA8C3d0s0   ONLINE       0     0     0
            c0t5000C500335FC3E7d0s0   ONLINE       0     0     0

errors: No known data errors
```

# Migrating ZFS Storage Pools

Occasionally, you might need to move a storage pool between systems. You would disconnect the storage devices from the original system and reconnect them to the destination system either by physically recabling the devices or by using multiported devices such as the devices on a SAN.

ZFS enables you to export the pool from one system and import it on the destination system even if the systems are of different architectural endianness. For information about replicating or migrating file systems between different storage pools, which might reside on different systems, see Saving, Sending, and Receiving ZFS Data.

## Preparing for ZFS Storage Pool Migration

To migrate a pool, you must first export it. This operation flushes any unwritten data to disk, writes data to the disk indicating that the export is complete, and removes all information about the pool from the system.

If you do not explicitly export the pool but instead remove the disks manually, you can still import the resulting pool on another system. However, you might lose the last few seconds of data transactions. Also, because the devices are no longer present, the pool will appear as `UNAVAIL` on the original system. By default, the destination system cannot import a pool that has not been explicitly exported. This condition is necessary to prevent you from accidentally importing an active pool that consists of network-attached storage that is still in use on another system.

## Exporting a ZFS Storage Pool

To export a pool, use the following command:

```
$ zpool export [option] pool
```

The command first unmounts any mounted file systems within the pool. If any of the file systems fail to unmount, you can forcefully unmount them by using the `-f` option. However, if ZFS volumes in the pool are in use, the operation fails even with the `-f` option. To export a pool with a ZFS volume, first ensure that all consumers of the volume are no longer active.

For more information, see ZFS Volumes.

After this command is executed, the pool is no longer visible on the system.

If devices are unavailable at the time of export, the devices cannot be identified as cleanly exported. If one of these devices is later attached to a system without any of the other working devices, it appears as potentially active.

## Determining Available Storage Pools to Import

After the pool has been removed from the system, you can attach the devices to the target system. You do not need to attach them under the same device name. ZFS detects any moved or renamed devices and adjusts the configuration appropriately. Note that ZFS can handle some situations in which only some of the devices are available. However, a successful pool migration depends on the overall health of all the devices.

Use the following general command syntax for all pool import operations:

```
$ zpool import [options] [pool|ID-number]
```

To discover available pools that can be imported, run the `zpool import` command without specifying pools. In the output, the pools are identified by names and unique number identifiers. If pools available for import share the same name, use the numeric identifier to import the correct pool.

If problems exist with a pool to be imported, the command output also provides the appropriate information to help you determine what action to take.

In the following example, one of the devices is missing but you can still import the pool because the mirrored data remains accessible.

```
$ zpool import
 pool: system1
    id: 4715259469716913940
 state: DEGRADED
status: One or more devices are unavailable.
action: The pool can be imported despite missing or damaged devices.  The
        fault tolerance of the pool may be compromised if imported.
config:

    system1                       DEGRADED
       mirror-0                   DEGRADED
         c0t5000C500335E106Bd0    ONLINE
         c0t5000C500335FC3E7d0    UNAVAIL  cannot open

device details:

         c0t5000C500335FC3E7d0    UNAVAIL   cannot open
         status: ZFS detected errors on this device.
                The device was missing.
```

In the following example, because two disks are missing from a RAID-Z virtual device, not enough redundant data exists to reconstruct the pool. With insufficient available devices, ZFS cannot import the pool.

```
$ zpool import
pool: mothership
    id: 3702878663042245922
 state: UNAVAIL
status: One or more devices are unavailable.
action: The pool cannot be imported due to unavailable devices or data.
config:

        mothership     UNAVAIL  insufficient replicas
          raidz1-0     UNAVAIL  insufficient replicas
```

```
            c8t0d0     UNAVAIL  cannot open
            c8t1d0     UNAVAIL  cannot open
            c8t2d0     ONLINE
            c8t3d0     ONLINE

device details:

        c8t0d0    UNAVAIL          cannot open
        status: ZFS detected errors on this device.
                The device was missing.

        c8t1d0    UNAVAIL          cannot open
        status: ZFS detected errors on this device.
                The device was missing.
```

# Importing ZFS Storage Pools

To import a specific pool, specify the pool name or its numeric identifier with the `zfs import` command. Additionally, you can rename a pool while importing it. For example:

```
$ zpool import system1 mpool
```

This command imports the exported pool `system1` and renames it `mpool`. The new pool name is persistent.

> **Note:**
>
> You cannot rename a pool directly. You can only change the name of a pool while exporting and importing the pool, which also renames the root dataset to the new pool name.

> **Caution:**
>
> During an import operation, warnings occur if the pool might be in use on another system.
>
> ```
> cannot import 'pool': pool may be in use on another system
> use '-f' to import anyway
> ```
>
> Do not attempt to import a pool that is active on one system to another system. ZFS is not a native cluster, distributed, or parallel file system and cannot provide concurrent access from multiple, different systems.

You can also import pools under an alternate root by using the `-R` option. For more information, see Using a ZFS Pool With an Alternate Root Location.

## Importing a Pool With a Missing Log Device

By default, a pool with a missing log device cannot be imported. You can use `zpool import -m` command to force a pool to be imported with a missing log device.

In the following example, the output indicates a missing mirrored log when you first import the pool `dozer`.

```
$ zpool import dozer
The devices below are missing, use '-m' to import the pool anyway:
mirror-1 [log]
c3t3d0
c3t4d0

cannot import 'dozer': one or more devices is currently unavailable
```

To proceed with importing the pool with the missing mirrored log, use the `-m` option.

```
$ zpool import -m dozer
$ zpool status dozer
pool: dozer
state: DEGRADED
status: One or more devices could not be opened.  Sufficient replicas exist for
the pool to continue functioning in a degraded state.
action: Attach the missing device and online it using 'zpool online'.
see: URL to My Oracle Support knowledge article
scan: scrub repaired 0 in 0h0m with 0 errors on Fri Oct 15 16:51:39 2010
config:

NAME                   STATE     READ  WRITE  CKSUM
dozer                  DEGRADED     0      0      0
   mirror-0            ONLINE       0      0      0
      c3t1d0           ONLINE       0      0      0
      c3t2d0           ONLINE       0      0      0
   logs
   mirror-1                 UNAVAIL      0     0     0  insufficient replicas
      13514061426445294202  UNAVAIL      0     0     0  was c3t3d0
      16839344638582008929  UNAVAIL      0     0     0  was c3t4d0
```

The imported pool remains in a `DEGRADED` state. Based on the output recommendation, attach the missing log devices. Then, run the `zpool clear` command to clear the pool errors.

## Importing a Pool in Read-Only Mode

If a pool is so damaged that it cannot be accessed, importing in read-only mode might enable you to recover the pool's data. For example:

```
$ zpool import -o readonly=on system1
$ zpool scrub system1
cannot scrub system1: pool is read-only
```

When a pool is imported in read-only mode, the following conditions apply:

- All file systems and volumes are mounted in read-only mode.
- Pool transaction processing is disabled. Any pending synchronous writes in the intent log are not made until the pool is imported in read-write mode.
- Setting a pool property during the read-only import is ignored.

You can set the pool back to read-write mode by exporting and importing the pool. For example:

```
$ zpool export system1
$ zpool import system1
$ zpool scrub system1
```

## Importing a Pool By Using a Specific Device Path

By default, the `zpool import` command searches devices only within the `/dev/dsk` directory. If devices exist in another directory, or you are using pools backed by files, you must use the `-d` option to search alternate directories. For example:

```
$ zpool create mpool mirror /file/a /file/b
$ zpool export mpool
$ zpool import -d /file
  pool: mpool
    id: 7318163511366751416
 state: ONLINE
action: The pool can be imported using its name or numeric identifier.
config:

        mpool        ONLINE
          mirror-0   ONLINE
            /file/a  ONLINE
            /file/b  ONLINE
$ zpool import -d /file mpool
```

If devices exist in multiple directories, you can specify multiple `-d` options.

The following command imports the pool `mpool` by identifying one of the pool's specific devices, `/dev/etc/c2t3d0`:

```
$ zpool import -d /dev/etc/c2t3d0 mpool
$ zpool status mpool
pool: mpool
state: ONLINE
scan: resilvered 952K in 0h0m with 0 errors on Fri Jun 29 16:22:06 2012
config:

NAME        STATE     READ WRITE CKSUM
mpool       ONLINE       0     0     0
mirror-0    ONLINE       0     0     0
  c2t3d0    ONLINE       0     0     0
  c2t1d0    ONLINE       0     0     0
```

## Recovering Destroyed ZFS Storage Pools

You can use the `zpool import -D` command to recover a storage pool that has been destroyed.

In the following example, the pool `system1` is indicated as destroyed.

```
$ zpool import -D
  pool: system1
    id: 5154272182900538157
 state: ONLINE (DESTROYED)
action: The pool can be imported using its name or numeric identifier.
config:

        system1     ONLINE
          mirror-0  ONLINE
            c1t0d0  ONLINE
            c1t1d0  ONLINE
```

To recover the destroyed pool, import it with the `-D` option.

```
$ zpool import -D system1
$ zpool status system1
  pool: system1
 state: ONLINE
 scrub: none requested
config:

        NAME        STATE     READ WRITE CKSUM
        system1     ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            c1t0d0  ONLINE       0     0     0
            c1t1d0  ONLINE       0     0     0

errors: No known data errors
```

If one of the devices in the destroyed pool is unavailable, you might still recover the destroyed pool by including the `-f` option. In this scenario, you would import the degraded pool and then attempt to fix the device failure. For example:

```
$ zpool import -D
  pool: dozer
    id: 4107023015970708695
 state: DEGRADED (DESTROYED)
status: One or more devices are unavailable.
action: The pool can be imported despite missing or damaged devices.  The
        fault tolerance of the pool may be compromised if imported.
config:

        dozer              DEGRADED
          raidz2-0         DEGRADED
            c8t0d0         ONLINE
            c8t1d0         ONLINE
            c8t2d0         ONLINE
            c8t3d0         UNAVAIL  cannot open
            c8t4d0         ONLINE

device details:

        c8t3d0    UNAVAIL          cannot open
        status: ZFS detected errors on this device.
                The device was missing.
$ zpool import -Df dozer
$ zpool status -x
  pool: dozer
 state: DEGRADED
status: One or more devices are unavailable in response to persistent errors.
        Sufficient replicas exist for the pool to continue functioning in a
        degraded state.
action: Determine if the device needs to be replaced, and clear the errors
        using 'zpool clear' or 'fmadm repaired', or replace the device
        with 'zpool replace'.
        Run 'zpool status -v' to see device specific details.
  scan: none requested
config:

        NAME                     STATE     READ WRITE CKSUM
        dozer                    DEGRADED     0     0     0
          raidz2-0               DEGRADED     0     0     0
            c8t0d0               ONLINE       0     0     0
            c8t1d0               ONLINE       0     0     0
            c8t2d0               ONLINE       0     0     0
            4881130428504041127  UNAVAIL      0     0     0
```

```
            c8t4d0              ONLINE       0     0     0

errors: No known data errors
$ zpool online dozer c8t3d0
$ zpool status -x
all pools are healthy
```

# Upgrading ZFS Storage Pools

With the `zpool upgrade` command, you can upgrade ZFS storage pools from a previous Oracle Solaris release.

Before using the command, use the `zpool status` command to check whether the pools were configured with a ZFS version that is previous to the version currently on the system. Also, consider displaying the features of the current ZFS version on the system by using the `-v` option as shown below:

```
$ zpool upgrade -v
```

The list of features would vary depending on the ZFS version number on the system. See ZFS Pool Versions for a complete list.

Use the `-a` option to upgrade the pools and take advantage of the latest ZFS features.

```
$ zpool upgrade -a
```

After you upgrade the pools, they are no longer accessible on a system that is running a previous ZFS version.

**Example 5-1 Upgrading ZFS Pools**

This example shows the actions to upgrade pools.

```
$ zpool status
  pool: system1
 state: ONLINE
status: The pool is formatted using an older on-disk format.  The pool can
        still be used, but some features are unavailable.
action: Upgrade the pool using 'zpool upgrade'.  Once this is done, the
        pool will no longer be accessible on older software versions.
 scrub: none requested
config:
        NAME        STATE     READ WRITE CKSUM
        system1     ONLINE       0     0     0
          mirror-0  ONLINE       0     0     0
            c1t0d0  ONLINE       0     0     0
            c1t1d0  ONLINE       0     0     0
errors: No known data errors

$ zpool upgrade -v
This system is currently running ZFS pool version version-number.

The following versions are supported:

VER  DESCRIPTION
---  --------------------------------------------------------
1    Initial ZFS version
2    Ditto blocks (replicated metadata)
3    Hot spares and double parity RAID-Z
4    zpool history
5    Compression using the gzip algorithm
```

```
.
.
Additional features

$ zpool upgrade -a
```

# Managing ZFS Pools That Contain Boot Environments

Starting with Oracle Solaris 11.4 SRU 30, you can use the `zpool` command to upgrade the version of ZFS pools (zpools) on your system without affecting the bootability of related boot environments (BEs). Also, you can use the `beadm` command to activate a BE. These commands compare zpool and `zfs` module pool versions and notify you when a pool upgrade would make related BEs unbootable and when a BE activation would fail.

- The `zpool upgrade` command upgrades a zpool that contains BEs to the specified system pool version. By default, the zpool is upgraded to the highest supportable pool version. However, if the upgrade would leave any related BEs unbootable, the upgrade fails.

  > **Note:**
  >
  > You cannot downgrade a zpool to an earlier version. If you attempt to import a zpool that has a version that is greater than the version of the `zfs` module, the operation fails.

  You can use the `zpool upgrade -f` command to force a zpool upgrade that would otherwise fail. However, if an active-on-boot BE would become unbootable if you update the zpool version, the `zpool upgrade` command fails even if you specify the `-f` option.

  Additionally, the `zpool` command has a `-n` option that performs a dry-run of an operation, such as an upgrade. The dry run of the operation reports the actions it would take without taking those actions.

  > **Note:**
  >
  > You can no longer use the `zpool set -o version=` *version* command to upgrade a bootable zpool. Instead, you must use the `zpool upgrade` command.

- The `beadm activate` command activates a BE as long as the version of the ZFS pool is less than or equal to the pool version of a BE's `zfs` module, otherwise the BE is unbootable.

**Example 5-2 Upgrading Pool Versions of ZPools That Contain Boot Environments**

This extended example shows how to use the `zpool` and `beadm` commands to upgrade the pool version of the `rpool` zpool that contains BEs. The example shows what happens when pool versions do not match and render related BEs unbootable and how you can address the situations.

The following command attempts to upgrade the versions of the zpools to the highest workable version, which is same as the system (`zfs` module) pool version of 47. This command also determines that the `rpool` pool is Version 44 and thus out of date.

```
# zpool upgrade
This system is currently running ZFS pool version 47.

The following pools are out of date, and can be upgraded.  After being
upgraded, these pools will no longer be accessible by older software versions.

VER  POOL
---  ------------
44   rpool

Use 'zpool upgrade -v' for a list of available versions and their associated
features.
```

The following command attempts to upgrade the `rpool` pool version from 44 to 47 and determines that the resulting upgrade would make related BEs unbootable.

```
# zpool upgrade rpool
This system is currently running ZFS pool version 47.

rpool is on version 44 and will not upgrade without making BEs un-bootable
```

To determine which BEs would be affected by the pool version upgrade, the following command performs a dry run of the previous command.

The output shows the following list of affected BEs and their pool versions.

```
# zpool upgrade -n -V 47 rpool
This system is currently running ZFS pool version 47.

Upgrading to version 47 will make these BEs un-bootable
FMRI           Pool Version
-------------- ------------
be://rpool/BE1 44
be://rpool/BE2 45
be://rpool/BE3 46
use "zpool upgrade -f -V 47 rpool" to force the upgrade.
```

The following command attempts to force the upgrade of `rpool` to Version 45 and determines that the upgrade would make the `be://rpool/BE1` BE unbootable. The command does not perform the upgrade.

```
# zpool upgrade -V 45 rpool
This system is currently running ZFS pool version 47.

Upgrading to version 45 will make this BE un-bootable
FMRI           Pool Version
-------------- ------------
be://rpool/BE1 44
use "zpool upgrade -f -V 45 rpool" to force the upgrade.
```

The following command forces the upgrade of `rpool` to Version 45. Because the `be://rpool/BE1` BE would remain at Version 44, it becomes unbootable.

```
# zpool upgrade -f -V 45 rpool
This system is currently running ZFS pool version 47.

Upgrading to version 45 will make this BE un-bootable
FMRI           Pool Version
-------------- ------------
be://rpool/BE1 44
Pool 'rpool' upgraded from version 44 to version 45
```

When a zpool version is greater than the version supported by a BE, that BE is unbootable and can no longer be activated. The `beadm list` output shows an exclamation mark (`!`) in the Flags column for unbootable BEs.

The following command attempts to activate `BE1` and states that the BE is no longer bootable because of mismatched versions.

```
# beadm activate BE1
Unable to activate BE BE1:
BE BE1 supports version 44, pool version is 45
```

If the BE that is active on next boot becomes unbootable, you cannot force the upgrade the pool version by using the `-f` option.

The following command successfully activates the `BE2` BE:

```
# beadm activate BE2
```

The following command lists information about existing BEs. The `-o` option enables you to specify the type of BE information to show: its name, pool version, and state flags. See the `beadm`(8) man page.

```
# beadm list -o name,pool_version,flags
BE Name          Pool Version Flags
---------------- ------------ -----
BE1              44           !
BE2              45           R
BE3              46           -
beadm            47           N
solaris          47           -
solaris-backup-1 47           -
```

The following command attempts to upgrade `rpool` to Version 46, but because this command would make `BE2` unbootable, the command does not perform the upgrade.

```
# zpool upgrade -V 46 rpool
This system is currently running ZFS pool version 47.

Upgrading to pool version 46 would make the active on boot BE 'BE2' un-bootable
```

The following command forces the upgrade of `rpool` to Version 46 and makes `BE2` unbootable.

```
# zpool upgrade -V 46 -f rpool
This system is currently running ZFS pool version 47.

Upgrading to pool version 46 would make the active on boot BE 'BE2' un-bootable
```

The following command attempts to upgrade the `rpool2` pool to Version 46. Because this command would make the `TestBE` BE unbootable, the command does not perform the upgrade.

```
# zpool upgrade -V 46 rpool2
This system is currently running ZFS pool version 47.

Upgrading to version 46 will make these BEs un-bootable
FMRI             Pool Version
---------------- ------------
TestBE           45
use "zpool upgrade -f -V 46 rpool2" to force the upgrade.
```

As long as the upgrade of the zpool does not make related BEs unbootable, the zpool is upgraded.

The following command destroys the `TestBE` BE. Because this BE is active on boot, the active BE, `be://rpool/beadm`, becomes active on boot.

```
# beadm destroy -F TestBE
Warning: BE to be destroyed is the active on boot BE.  Making current active BE, be://
rpool/beadm, to be the active on boot BE.
```

The following command succesfully upgrades `rpool2` to Version 46 because the previously unbootable BE, `TestBE`, no longer exists.

```
# zpool upgrade -V 46 rpool2
This system is currently running ZFS pool version 47.

Pool 'rpool2' upgraded from version 45 to version 46
```

The following command fails to upgrade `rpool2` to the highest possible version because upgrading the pool would make other BEs unbootable.

```
# zpool upgrade rpool2
This system is currently running ZFS pool version 47.

rpool2 is on version 46 and will not upgrade without making more BEs un-bootable
```

You can perform a dry-run of the previous command to discover the affected BEs.

6

# Managing the ZFS Root Pool

This chapter describes how to manage the Oracle Solaris ZFS root pool and its components. It covers the following topics:

- Requirements for Configuring the ZFS Root Pool
- Managing a ZFS Root Pool
- Managing ZFS Swap and Dump Devices
- Booting From a ZFS Root File System

For information about root pool recovery, see *Using Unified Archives for System Recovery and Cloning in Oracle Solaris 11.4* .

## Requirements for Configuring the ZFS Root Pool

ZFS is the default root file system of Oracle Solaris. The root pool contains the boot environment (BE) and is automatically created during the installation.

### ZFS Root Pool Space Requirements

The size of the swap dump volumes depend on the amount of physical memory. The minimum amount of pool space for a bootable ZFS root file system depends upon the amount of physical memory, the disk space available, and the number of BEs to be created.

The 7GB to 13GB minimum disk space recommended in Hardware and Software Requirements is consumed as follows:

- Swap area and dump device – The default sizes of the swap and dump volumes that the installation program creates vary based on variables such as the amount of system memory. The dump device size is approximately half the size of physical memory or greater, depending on the system's activity.

  You can adjust the sizes of your swap and dump volumes during or after installation. The new sizes must support system operation. See Adjusting the Sizes of ZFS Swap and Dump Devices.
- Boot environment – A ZFS BE is approximately 4 GB-6 GB. Each ZFS BE that is cloned from another ZFS BE does not need additional disk space. The BE size will increase when it is updated, depending on the updates. All ZFS BEs in the same root pool use the same swap and dump devices.
- Oracle Solaris Components – All subdirectories of the root file system except `/var` that are part of the OS image must be in the root file system. All Oracle Solaris components except the swap and dump devices must reside in the root pool.

### ZFS Root Pool Configuration Recommendations

Follow these guidelines when configuring the ZFS root pool:

- If you are using EFI (GPT) labeled disks, create the root pool on mirrored whole disks. If you are using SMI (VTOC) labeled disks, create the root pool on mirrored slices.

In most cases, x86 systems and SPARC systems with GPT aware firmware have EFI (GPT) labeled disks. Otherwise, SPARC systems have SMI (VTOC) labeled disks.

- Do not rename the root pool that is created after an initial installation because the system might become unbootable. Also, as best practice, do not change any default settings, such as the mountpoint, of the root pool. Otherwise, errors might occur in subsequent operations on the boot environment.
- Do not use a thinly provisioned VMware device for a root pool device.

Root pools have the following limitations:

- RAID-Z or striped configurations are not supported for root pools.
- Root pools cannot have a separate log device.
- You cannot configure multiple top-level virtual devices on root pools. However, you can expand a mirrored root pool by attaching additional devices.
- The `gzip` and `lz4` compression algorithms are not supported on root pools.

## Installing the ZFS Root Pool

As documented in *Manually Installing an Oracle Solaris 11.4 System* , you can use text installer or Automated Installer (AI) with the AI manifest to install Oracle Solaris. Both methods automatically install a ZFS root pool on a single disk. The installation also configures swap and dump devices on ZFS volumes on the root pool.

> **Note:**
>
> Starting with Oracle Solaris 11.4 SRU 36, the `compression` property is set to `on` by default. This property setting reduces space consumption in the root pool and might improve system performance.

The AI method offers more flexibility in installing the root pool. In the AI manifest, you can specify the disks to use to create a mirrored root pool as well as enable ZFS properties, as shown in Modifying the AI Manifest to Customize Root Pool Installation.

After Oracle Solaris is completely installed, perform the following actions:

- If the installation created a root pool on a single disk, then manually convert the pool into a mirrored configuration. See How to Configure a Mirrored Root Pool (SPARC or x86/VTOC).
- Set a quota on the ZFS root file system to prevent the root file system from filling up. Currently, no ZFS root pool space is reserved as a safety net for a full file system. For example, if you have a 68 GB disk for the root pool, consider setting a 67 GB quota on the ZFS root file system (`rpool/ROOT/solaris`) to allow for 1 GB of remaining file system space. See Setting Quotas on ZFS File Systems.
- Create a root pool recovery archive for disaster recovery or for migration purposes by using the Oracle Solaris archive utility. For more information, refer to *Using Unified Archives for System Recovery and Cloning in Oracle Solaris 11.4* and the `archiveadm`(8) man page.

**Example 6-1 Modifying the AI Manifest to Customize Root Pool Installation**

This example shows how to customize the AI manifest to perform the following:

- Create a mirrored root pool consisting of `c1t0d0` and `c2t0d0`.

- Enable the root pool's `listsnaps` property.

```
<target>
<disk whole_disk="true" in_zpool="rpool" in_vdev="mirrored">
<disk_name name="c1t0d0" name_type="ctd"/>
</disk>
<disk whole_disk="true" in_zpool="rpool" in_vdev="mirrored">
<disk_name name="c2t0d0" name_type="ctd"/>
</disk>
<logical>
<zpool name="rpool" is_root="true">
<vdev name="mirrored" redundancy="mirror"/>
<!--
...
-->
<filesystem name="export" mountpoint="/export"/>
<filesystem name="export/home"/>
<pool_options>
<option name="listsnaps" value="on"/>
</pool_options>
<be name="solaris"/>
</zpool>
</logical>
</target>
```

### Example 6-2 Sample Root Pool Configuration

The following example shows a mirrored root pool and file system configuration after an AI installation with a customized manifest.

```
$ zpool status rpool
pool: rpool
state: ONLINE
scan: none requested
config:

NAME          STATE     READ WRITE CKSUM
rpool         ONLINE       0     0     0
   mirror-0   ONLINE       0     0     0
     c8t0d0   ONLINE       0     0     0
     c8t1d0   ONLINE       0     0     0

$ zfs list
NAME                      USED  AVAIL  REFER  MOUNTPOINT
rpool                    11.8G  55.1G  4.58M  /rpool
rpool/ROOT               3.57G  55.1G    31K  legacy
rpool/ROOT/solaris       3.57G  55.1G  3.40G  /
rpool/ROOT/solaris/var    165M  55.1G   163M  /var
rpool/VARSHARE           42.5K  55.1G  42.5K  /var/share
rpool/dump               6.19G  55.3G  6.00G  -
rpool/export               63K  55.1G    32K  /export
rpool/export/home          31K  55.1G    31K  /export/home
rpool/swap               2.06G  55.2G  2.00G  -
```

# Managing a ZFS Root Pool

This section provides procedures for managing the ZFS root pool.

# How to Configure a Mirrored Root Pool (SPARC or x86/EFI (GPT))

This procedure describes how to convert the default root pool installation into a redundant configuration. This procedure applies to most x86 systems and SPARC systems with GPT-aware firmware whose disks have the EFI (GPT) label.

1. **Display the current root pool status.**

   ```
   $ zpool status root-pool
   ```

2. **Attach a second disk to configure a mirrored root pool.**

   ```
   $ zpool attach root-pool current-disk new-disk
   ```

   The correct disk labeling and the boot blocks are applied automatically.

3. **View the root pool status to confirm that resilvering is complete.**

   If resilvering has been completed, the output includes a message similar to the following:

   ```
   scan: resilvered 11.6G in 0h5m with 0 errors on Fri Jul 20 13:57:25 2014
   ```

4. **If the new disk is larger than the current disk, enable the ZFS autoexpand property.**

   ```
   $ zpool set autoexpand=on root-pool
   ```

   The following example shows the difference in the `rpool`'s disk space after the `autoexpand` property is enabled.

   ```
   $ zpool list rpool
   NAME   SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
   rpool  29.8G   152K  29.7G   0%  1.00x  ONLINE  -
   $ zpool set autoexpand=on rpool
   $ zpool list rpool
   NAME   SIZE  ALLOC  FREE  CAP  DEDUP  HEALTH  ALTROOT
   rpool  279G   146K  279G   0%  1.00x  ONLINE  -
   ```

5. **Verify that you can boot successfully from the new disk.**

> **Note:**
>
> Unexpected behavior might occur if the ZFS configuration consists of a root file system that is built on mirrored iSCSI targets and the second LUN is not available on the same iSCSI target or session as the boot disk. When the system is booted, the boot process would report that opening the second iSCSI LUN failed and the root pool is in a degraded state. However, this status is temporary. The issue automatically resolves after the ZFS performs a quick resilvering. The second LUN then goes online and the state of the root pool goes online as well.

# How to Configure a Mirrored Root Pool (SPARC or x86/VTOC)

Prepare the second disk to attach to the root pool as follows:

- SPARC: Confirm that the disk has an SMI (VTOC) disk label and that slice 0 contains the bulk of the disk space. If you need to relabel the disk and create a slice 0, see How to Replace a ZFS Root Pool Disk in *Managing Devices in Oracle Solaris 11.4* .

- x86: Confirm that the disk has an `fdisk` partition, an SMI disk label, and a slice 0. If you need to repartition the disk and create a slice 0, see Modifying Slices or Partitions in *Managing Devices in Oracle Solaris 11.4* .

This procedure describes how to convert the default root pool installation into a redundant configuration. This procedure applies to certain x86 systems and SPARC systems without GPT-aware firmware whose disks have the SMI (VTOC) label.

1. **Display the current root pool status.**

   ```
   $ zpool status root-pool
   ```

   The configuration would display the disk's slice 0, as shown in the following example for `rpool`.

   ```
   $ zpool status rpool
   pool: rpool
   state: ONLINE
   scrub: none requested
   config:

   NAME        STATE     READ WRITE CKSUM
   rpool       ONLINE       0     0     0
   c2t0d0s0    ONLINE       0     0     0

   errors: No known data errors
   ```

2. **Attach the second disk to configure a mirrored root pool.**

   ```
   $ zpool attach root-pool current-disk new-disk
   ```

   Make sure that you include the slice when specifying the disk, such as `c2t0d0s0`. The correct disk labeling and the boot blocks are applied automatically.

3. **View the root pool status to confirm that resilvering is complete.**

   If resilvering has been completed, the output includes a message similar to the following:

   ```
   scan: resilvered 11.6G in 0h5m with 0 errors on Fri Jul 20 13:57:25 2014
   ```

4. **If the new disk is larger than the current disk, enable the ZFS autoexpand property.**

   ```
   $ zpool set autoexpand=on root-pool
   ```

   The following example shows the difference in the `rpool`'s disk space after the `autoexpand` property is enabled.

   ```
   $ zpool list rpool
   NAME   SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
   rpool  29.8G   152K  29.7G   0%  1.00x  ONLINE  -
   $ zpool set autoexpand=on rpool
   $ zpool list rpool
   NAME   SIZE  ALLOC  FREE  CAP  DEDUP  HEALTH  ALTROOT
   rpool  279G   146K  279G   0%  1.00x  ONLINE  -
   ```

5. **Verify that you can boot successfully from the new disk.**

> **Note:**
>
> Unexpected behavior might occur if the ZFS configuration consists of a root file system that is built on mirrored iSCSI targets and the second LUN is not available on the same iSCSI target or session as the boot disk. When the system is booted, the boot process would report that opening the second iSCSI LUN failed and the root pool is in a degraded state. However, this status is temporary. The issue automatically resolves after the ZFS performs a quick resilvering. The second LUN then goes online and the state of the root pool goes online as well.

## How to Update a ZFS Boot Environment

By default, the ZFS BE is named `solaris`. The `pkg update` command updates the ZFS BE by creating and automatically activating a new BE, provided that significant differences exist between the current and updated BEs.

1. **View the current boot environment configuration.**

   The BE's `Active` field shows `N` to indicate that the BE is active, `R` to indicate that it becomes active after a system reboot, or both (`NR`).

   ```
   $ beadm list
   BE       Active  Mountpoint  Space  Policy  Created
   --      ------ ---------- ----- ------ -------
   solaris  NR      /          3.82G  static  2012-07-19 13:44
   ```

2. **Update the ZFS BE.**

   ```
   $ pkg update
   .
   DOWNLOAD                                  PKGS       FILES    XFER (MB)
   Completed                                707/707 10529/10529  194.9/194.9
   .
   ```

   A new BE, `solaris-1`, is created automatically and activated.

3. **Reboot the system to complete the BE activation. Then, confirm the BE status.**

   ```
   $ init 6
   .
   .
   $ beadm list
   BE         Active  Mountpoint  Space   Policy  Created
   --         ------ ---------- -----  ------ -------
   solaris    -      -           46.95M   static  2014-07-20 10:25
   solaris-1  NR      /           3.82G   static  2014-07-19 14:45
   ```

4. **If an error occurs when booting the new BE, activate and boot the previous BE.**

   ```
   $ beadm activate solaris
   $ init 6
   ```

   You use the same `beadm activate` *BE* command syntax to activate an existing backup BE independent of any update operation.

## How to Mount an Alternate BE

1. **Become an administrator.**
2. **Mount the alternate BE.**

```
$ beadm mount alt-BE /mnt
```

3. **Access the BE.**

```
$ ls /mnt
```

4. **Unmount the alternate BE when you're finished.**

```
$ beadm umount alt-BE
```

# Replacing Disks in a ZFS Root Pool

You might need to replace a disk in the root pool for the following reasons:

- The root pool is too small and you want to replace it with a larger disk
- The root pool disk is failing. In a non-redundant pool, if the disk is failing and the system no longer boots, boot from another source such as a CD or the network. Then, replace the root pool disk.

You can replace disks by using one of two methods:

- Using the `zpool replace` command.

  This method involves scrubbing and clearing the root pool of dirty time logs (DTLs), then replacing the disk. After the new disk is installed, you apply the boot blocks manually.

- Using the `zpool detach|attach` commands.

  This method involves attaching the new disk and verifying that it is working properly, then detaching the faulty disk.

If you are replacing root pool disks that have the SMI (VTOC) label, ensure that you fulfill the following requirements:

- SPARC: Confirm that the disk has an SMI (VTOC) disk label and a slice 0 that contains the bulk of the disk space. If you need to relabel the disk and create a slice 0, see How to Replace a ZFS Root Pool Disk in *Managing Devices in Oracle Solaris 11.4* .
- x86: Confirm that the disk has an `fdisk` partition, an SMI disk label, and a slice 0. If you need to repartition the disk and create a slice 0, see Modifying Slices or Partitions in *Managing Devices in Oracle Solaris 11.4* .

## How to Replace a Disk in a ZFS Root Pool

This procedure uses the `zpool attach|detach` commands to replace the disk.

1. **Physically connect the replacement disk.**
2. **Attach the new disk to the root pool.**

```
$ zpool attach root-pool current-disk new-disk
```

Where *current-disk* becomes *old-disk* to be detached at the end of this procedure.

The correct disk labeling and the boot blocks are applied automatically.

> **Note:**
>
> If the disks have SMI (VTOC) labels, make sure that you include the slice when specifying the disk, such as `c2t0d0s0`.

3. **View the root pool status to confirm that resilvering is complete.**

   If resilvering has been completed, the output includes a message similar to the following:

   ```
   scan: resilvered 11.6G in 0h5m with 0 errors on Fri Jul 20 13:57:25 2014
   ```

4. **Verify that you can boot successfully from the new disk.**
5. **After a successful boot, detach the old disk.**

   ```
   $ zpool detach root-pool old-disk
   ```

   Where *old-disk* is the *current-disk* of Step 2.

   > **Note:**
   >
   > If the disks have SMI (VTOC) labels, make sure that you include the slice when specifying the disk, such as `c2t0d0s0`.

6. **If the attached disk is larger than the existing disk, enable the ZFS autoexpand property.**

   ```
   $ zpool set autoexpand=on root-pool
   ```

7. **Set the system to boot automatically from the new disk.**
   - SPARC: Use either the `eeprom` command or the `setenv` command from the boot PROM.
   - x86: Reconfigure the system BIOS.
8. **If necessary, physically remove the replaced disk from the system.**

**Example 6-3 Replacing a Disk in a ZFS Root Pool (SPARC or x86/EFI (GPT))**

This example replaces `c2t0d0` in the root pool named `rpool` by using the `zpool attach|detach` commands. It assumes that the replacement disk `c2t1d0` is already physically connected to the system.

```
$ zpool attach rpool c2t0d0 c2t1d0
Make sure to wait until resilver is done before rebooting.

$ zpool status rpool
pool: rpool
state: ONLINE
scan: resilvered 11.7G in 0h5m with 0 errors on Fri Jul 20 13:45:37 2012
config:

NAME         STATE   READ  WRITE  CKSUM
rpool        ONLINE     0      0      0
  mirror-0   ONLINE     0      0      0
    c2t0d0   ONLINE     0      0      0
    c2t1d0   ONLINE     0      0      0

errors: No known data errors
```

After completing the boot test from the new disk `c2t1d0`, you would detach `c2t0d0` and, if necessary, enable the `autoexpand` property.

```
$ zpool detach rpool c2t0d0
$ zpool list rpool
NAME   SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
rpool  29.8G   152K  29.7G   0%  1.00x  ONLINE  -
```

```
$ zpool set autoexpand=on rpool
$ zpool list rpool
NAME   SIZE  ALLOC  FREE  CAP  DEDUP  HEALTH  ALTROOT
rpool  279G   146K  279G   0%  1.00x  ONLINE  -
```

You would complete the operation by setting the system to automatically boot from the new disk.

### Example 6-4 Replacing SATA Disks in a Root Pool (SPARC or x86/EFI (GPT))

This example replaces `c1t0d0` by using the `zpool replace` command.

Systems with SATA disks require that before replacing a failed disk with the `zpool replace` command, you take the disk offline and unconfigure it. As a best practice, scrub and clear the root pool first before replacing the disk.

Suppose that you are replacing `c1t0d0` on the system. You would issue the following commands:

```
$ zpool scrub rpool
$ zpool clear rpool
$ zpool offline rpool c1t0d0
$ cfgadm -c unconfigure c1::dsk/c1t0d0
```

At this point, you would physically remove the failed disk `c1t0d0` and insert the replacement disk on the same slot. Thus, the new disk is still `c1t0d0`. On some hardware, you do not have to bring the disk online or reconfigure the replacement disk after it is inserted.

```
$ cfgadm -c configure c1::dsk/c1t0d0
$ zpool online rpool c1t0d0
$ zpool replace rpool c1t0d0
$ zpool status rpool
```

After resilvering is completed, you would install the boot blocks.

```
$ bootadm install-bootloader
```

### Example 6-5 Replacing a Disk in a ZFS Root Pool (SPARC or x86/VTOC)

This example uses the `zpool attach|detach` commands to replace `c2t0d0s0` in the root pool named `rpool`. It assumes that the replacement disk `c2t1d0s0` is already physically connected to the system.

```
$ zpool attach rpool c2t0d0s0 c2t1d0s0
Make sure to wait until resilver is done before rebooting.

$ zpool status rpool
pool: rpool
state: ONLINE
scan: resilvered 11.7G in 0h5m with 0 errors on Fri Jul 20 13:45:37 2012
config:

NAME          STATE   READ  WRITE  CKSUM
rpool         ONLINE     0      0      0
  mirror-0    ONLINE     0      0      0
    c2t0d0s0  ONLINE     0      0      0
    c2t1d0s0  ONLINE     0      0      0

errors: No known data errors
```

You would test booting from the new disk `c2t1d0s0`. You would also test booting from the old disk `c2t0d0s0` in case `c2t1d0s0` fails.

```
ok boot /pci@1f,700000/scsi@2/disk@1,0

ok boot /pci@1f,700000/scsi@2/disk@0,0
```

After completing the boot tests, you would detach `c2t0d0s0` and, if necessary, enable the `autoexpand` property.

```
$ zpool detach rpool c2t0d0s0
$ zpool list rpool
NAME    SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
rpool  29.8G   152K  29.7G   0%  1.00x  ONLINE  -
$ zpool set autoexpand=on rpool
$ zpool list rpool
NAME    SIZE  ALLOC  FREE  CAP  DEDUP  HEALTH  ALTROOT
rpool  279G   146K  279G   0%  1.00x  ONLINE  -
```

You would complete the operation by setting the system to automatically boot from the new disk.

**Example 6-6 Replacing SATA Disks in a Root Pool (SPARC or x86 (VTOC))**

This example replaces `c1t0d0` by using the `zpool replace` command.

Systems with SATA disks require that before replacing a failed disk with the `zpool replace` command, you take the disk offline and unconfigure it. As a best practice, scrub and clear the root pool first before replacing the disk.

Suppose that you are replacing `c1t0d0` on the system. You would issue the following commands:

```
$ zpool scrub rpool
$ zpool clear rpool
$ zpool offline rpool c1t0d0s0
$ cfgadm -c unconfigure c1::dsk/c1t0d0
```

At this point, you would physically remove the failed disk `c1t0d0` and insert the replacement disk on the same slot. Thus the new disk is still `c1t0d0`. On some hardware, you do not have to bring the disk online or reconfigure the replacement disk after it is inserted.

```
$ cfgadm -c configure c1::dsk/c1t0d0
```

After confirming that the replacement disk `c1t0d0s0` has an SMI label and a slice 0, you would issue the `zpool replace` command and proceed with the replacement process.

```
$ zpool replace rpool c1t0d0s0
$ zpool online rpool c1t0d0s0
$ zpool status rpool
```

After resilvering is completed, you install the boot blocks.

```
$ bootadm install-bootloader
```

# Managing ZFS Swap and Dump Devices

The installation process automatically creates a swap area and a dump device on a ZFS volume in the ZFS root pool.

The dump device is used when the directory where crash dumps are saved has insufficient space, or if you ran the `dumpadm -n` command syntax. The `-n` modifies the dump configuration to not run `savecore` automatically running after a system reboot.

Certain systems avail of the deferred dump feature in the current Oracle Solaris release. With this feature, a system dump is preserved in memory across a system reboot to enable you to analyze the crash dump after the system reboots. For more information, see About Devices and the Oracle Hardware Management Pack in *Managing Devices in Oracle Solaris 11.4* .

Note the following guidelines when managing swap and dump volumes:

- During a Solaris installation, a dump device is automatically created in the root pool. This is the recommended location for dump and swap devices. If the root pool is too small for the dump device, it can be relocated to a non-root pool. The non-root pool must be either a single-disk pool, a mirrored pool, or a striped pool. Dump devices are not supported on a RAIDZ pool.
- ZFS volumes that are used for swap are always encrypted by using an ephemeral key.
- Sparse volumes are not supported for swap volumes.
- Currently, using a swap file on a ZFS file system is not supported.

# Viewing Swap and Dump Information

To view the swap area, use the `swap -l` command. For example:

```
$ swap -l
swapfile                  dev    swaplo   blocks     free
/dev/zvol/dsk/rpool/swap 145,2        16 16646128 16646128
```

To view the dump configuration, use the `dumpadm` command. For example:

```
$ dumpadm
Dump content: kernel pages
Dump device: /dev/zvol/dsk/rpool/dump (dedicated)
Savecore directory: /var/crash/
Savecore enabled: yes
Save compressed: on
```

You can also manually create swap or dump volumes in a non-root pool. After creating a dump device on the non-root pool, you must also reset it by running the `dump -d` command.

In the following example, a dump device is created on the non-root pool `bpool`.

```
$ zfs create -V 10g bpool/dump2
$ dumpadm -d /dev/zvol/dsk/bpool/dump2
Dump content      : kernel with ZFS metadata
Dump device       : /dev/zvol/dsk/bpool/dump2 (dedicated)
Savecore directory: /var/crash
Savecore enabled  : yes
Save compressed   : on
```

## How to Create a Swap Volume

This procedure applies to both root pools and non-root pools. If you need more swap space but the existing pool is not large enough, just add another swap volume by using this same procedure. The procedure adds the swap volume permanently such that the swap volume is added on each boot.

1. **Create a ZFS volume to use as swap.**

   ```
   $ zfs create -V size new-pool/swap
   ```

2. **Activate the new swap volume.**

```
$ swap -a new-pool/swap
```

3. **If necessary, reboot the system.**

**Example 6-7 Manually Creating a Swap Volume**

This example creates a new 4 GB swap volume in the `rpool2` pool. This new swap volume is intended to replace an existing swap volume.

```
$ zfs create -V 4g rpool2/swap2
$ swap -a rpool2/swap2
```

## How to Delete a Swap Volume

This procedure applies to both root pools and non-root pools.

1. **Deactivate the swap volume.**

```
$ swap -d pool/swap
```

2. **Delete the ZFS swap volume.**

```
$ zfs destroy pool/swap
```

**Example 6-8 Manually Deleting a Swap Volume**

This example deletes the `swap2` swap volume in the `rpool2` pool.

```
$ swap -d rpool2/swap2
$ zfs destroy rpool2/swap2
```

## How to Create a Dump Volume

This procedure applies whether you are using a root pool or a non-root pool.

1. **Create a ZFS volume to use for dump.**

```
$ zfs create -V size new-pool/dump
```

2. **Activate the new swap volume.**

```
$ dumpadm -d new-pool/dump
```

3. **(Optional) Activate swap on the dump volume.**

```
$ swap -a new-pool/dump
```

4. **If necessary, reboot the system.**

**Example 6-9 Manually Creating a Dump Volume**

This example creates a new 4 GB dump volume in the `rpool2` pool.

```
$ zfs create -V 4g rpool2/dump
$ dumpadm -d rpool2/dump
```

# Adjusting the Sizes of ZFS Swap and Dump Devices

After installation, you might need to adjust the size of swap and dump devices after installation. Or you might need to recreate the swap and dump volumes.

By default, when you specify *n* blocks for the swap size, if the device is not a ZFS volume, the first page of the swap file is automatically skipped. Thus, the actual size that is assigned is *n*-1 blocks. To configure the swap file size differently, use the `swaplow` option with the `swap`

command. For more information about the options for the `swap` command, see the `swap`(8) man page.

The following examples show how to adjust existing swap and dump devices under different circumstances.

**Example 6-10 Resetting the Dump Device `volsize` Property**

Note that resizing a large dump device can be a time-consuming process.

```
$ zfs set volsize=2G rpool/dump
$ zfs get volsize rpool/dump
NAME         PROPERTY  VALUE        SOURCE
rpool/dump   volsize   2G           -
```

**Example 6-11 Resizing the Swap Volume for Immediate Use**

This example shows how to adjust the size of the swap volume.

```
$ swap -l
swapfile                     dev    swaplo   blocks     free  encrypted
/dev/zvol/dsk/rpool/swap   230,5         0  2097152  2097152        yes
$ zfs get volsize rpool/swap
NAME          PROPERTY   VALUE    SOURCE
rpool/swap    volsize       1G     local
$ zfs set volsize=2g rpool/swap
$ swap -l
swapfile                     dev    swaplo   blocks     free  encrypted
/dev/zvol/dsk/rpool/swap   230,5         0  2097152  2097152        yes
/dev/zvol/dsk/rpool/swap   230,5   2097152  2097152  2097152        yes
```

You will see two swap entries temporarily, but you will have access to the extended swap space.

# Troubleshooting ZFS Dump Device Issues

This section describes certain issues and possible resolutions related to dump devices.

- The size of the dump device is too small.

  When you reset the dump device, the output includes a message similar to the following:

  ```
  dumpadm: dump device dump-path is too small to hold a system dump
  ```

  To resolve this error, increase the size of the dump device. See Adjusting the Sizes of ZFS Swap and Dump Devices.

- The dump device is disabled.

  If necessary, create a new dump device and enable it by using the `dumpadm -d` command. See How to Create a Dump Volume.

- If the root pool is too small for the dump device, it can be added to a non-root pool as long as the pool is not a RAIDZ pool.

  When you reset the dump device, the output includes a message similar to the following:

  ```
  dump is not supported on device 'dump-path':
  'pool' has multiple top level vdevs
  ```

  Adding a dump device to pools with multiple top-level devices is not supported. Add the dump device to the root pool instead. Root pools support only a single top-level configuration.

- A crash dump was not created automatically.

  In this case, use the `savecore` command to save the crash dump.

# Booting From a ZFS Root File System

Both SPARC based and x86 based systems boot with a boot archive, which is a file system image that contains the files required for booting. The root file system that is selected for booting contains the path names of both the boot archive and the kernel file.

In the case of a ZFS boot, a device specifier identifies a storage pool, not a single root file system. A storage pool can contain multiple bootable ZFS root file systems. Thus, you must specify a boot device and a root file system within the pool that was identified by the boot device.

By default, a ZFS boot process uses the file system that is defined in the pool's `bootfs` property. However, you can override the default file system. On SPARC systems, you can use the `boot -Z` command and specify an alternate bootable file system. On x86 systems, you can select an alternate boot device from the BIOS.

If you replace a root pool disk with the `zpool replace` command, you must install the boot information on the replacement disk. However, installing the boot information is not required if you merely attach additional disks to the root pool.

To install the boot information, use the `bootadm` command in one of the following ways:

- To install the boot information on the existing root pool's disk, use the following command:

  ```
  $ bootadm install-bootloader
  ```

- To install the boot information on an alternate pool, use the following command:

  ```
  $ bootadm install-bootloader -P alt-root-pool
  ```

## Booting From an Alternate Root Pool Disk

> **Note:**
>
> The information in this section applies only to mirrored root pools.

When booting from an alternate root pool disk, ensure that all the root pool's disks are attached and online so you can boot from any of the disks, if necessary. On most systems, you cannot boot directly from a disk that has been detached, or boot from an active root pool disk that is currently offline.

### Alternate Boot Disks on SPARC Systems

The primary disk in a mirrored root pool is typically the default boot device. To boot from a different device, you must specify that disk when issuing the command to boot.

If you want to change the default boot device, first display the pool's configuration to select the device you want. Then, at the `OK` prompt, update the system's PROM with the selected device. Boot the system and confirm that your selected device is the active boot device.

The following example assigns `c1t1d0` as the default boot device.

```
$ zpool status
pool: rpool
state: ONLINE
scrub: none requested
config:

NAME        STATE     READ  WRITE CKSUM
rpool       ONLINE    0     0     0
  mirror-0  ONLINE    0     0     0
    c1t0d0  ONLINE    0     0     0
    c1t1d0  ONLINE    0     0     0
...

ok boot /pci@7c0/pci@0/pci@1/pci@0,2/LSILogic,sas@2/disk@1
```

After the system is rebooted, you would confirm which active boot device is in the system.

```
$ prtconf -vp | grep bootpath
bootpath:  '/pci@7c0/pci@0/pci@1/pci@0,2/LSILogic,sas@2/disk@1,0:a'
```

## Alternate Boot Disks on x86 Systems

On x86 based systems with a modern BIOS where the boot disk order is properly set, the system boots automatically from the second device if the primary root pool disk is detached, offline, or unavailable. In such systems, you merely need to confirm which active boot device is in the system, as shown in the following example.

```
$ prtconf -v|sed -n '/bootpath/,/value/p'
name='bootpath' type=string items=1
value='/pci@0,0/pci8086,25f8@4/pci108e,286@0/disk@0,0:a'
```

# Booting From a ZFS Root File System on a SPARC Based System

On a system with multiple ZFS BEs, you can boot from any BE by using the `beadm activate` command. Both the installation process and the `beadm` activation process automatically set the `bootfs` property.

By default, the `bootfs` property identifies the bootable file system entry in the `/` *pool-name* `/boot/menu.lst` file. However, a `menu.lst` entry can contain a `bootfs` command that specifies an alternate file system in the pool. Thus, the `menu.lst` file can contain entries for multiple root file systems within the pool.

When a ZFS root file system is installed, an entry similar to the following example is added to the `menu.lst` file:

```
title release-version SPARC
bootfs rpool/ROOT/solaris
```

When a new BE is created, the `menu.lst` file is updated automatically.

```
title release-version SPARC
bootfs rpool/ROOT/solaris
title solaris
bootfs rpool/ROOT/solaris2
```

## SPARC: How to Select the Boot Environment for Booting

1. **After a ZFS BE is activated, display a list of bootable file systems within a ZFS pool.**

   ```
   $ boot -L
   ```

2. **Select one of the bootable file systems in the list.**

   Detailed instructions for booting that file system are displayed.

3. **Boot the selected file system by following the instructions.**
4. **Use the boot -Z filesystem command to boot a specific ZFS file system.**
5. **To make the selected BE persistent across reboots, activate the BE.**

**Example 6-12 Booting From a Specific ZFS Boot Environment**

If you have multiple ZFS BEs in a ZFS storage pool on your system's boot device, use the `beadm activate` command to specify a default BE.

In this example, the `beadm` lists following available ZFS BEs:

```
$ beadm list
BE        Active Mountpoint Space Policy Created
--        ------ ---------- ----- ------ -------
solaris   NR     /          3.80G static 2012-07-20 10:25
solaris-2 -      -          7.68M static 2012-07-19 13:44
```

To select a specific BE, you would use the `boot -L` command. For example:

```
ok boot -L
Boot device: /pci@7c0/pci@0/pci@1/pci@0,2/LSILogic,sas@2/disk@0,0:a  File and args: -L
1 release-version SPARC
2 solaris
Select environment to boot: [ 1 - 2 ]: 1

To boot the selected entry, invoke:
boot [<root-device>] -Z rpool/ROOT/solaris-2

Program terminated
ok boot -Z rpool/ROOT/solaris-2
```

To boot automatically from the selected BE, activate that BE.

# Booting From a ZFS Root File System on an x86 Based System

Starting in Oracle Solaris 11.1, x86 based systems are installed with GRUB2. The `menu.lst` file is replaced by the `/rpool/boot/grub/grub.cfg` file. Do not edit this file manually. Instead, use the `bootadm` sub commands to add, change, and remove menu entries.

> **Note:**
>
> If your system's Oracle Solaris version still uses legacy GRUB, see Booting From a ZFS Root File System on an x86 Based System, which describes ZFS root file system entries in the `menu.lst` file.

For more information about modifying the GRUB menu items, see *Booting and Shutting Down Oracle Solaris 11.4 Systems* .

## x86: Displaying the Root File System

When booting from a ZFS root file system on a GRUB2 system, the root device is specified as follows:

```
$ bootadm list-menu
the location of the boot loader configuration files is: /rpool/boot/grub
default 0
console text
timeout 30
0 release-version
```

## x86: Fast Rebooting a ZFS Root File System

The fast reboot feature provides the ability to reboot within seconds on x86 based systems. With the fast reboot feature, you can reboot to a new kernel without experiencing the long delays that can be imposed by the BIOS and boot loader.

You must still use the `init 6` command when transitioning between BEs with the `beadm activate` command. For other system operations, use the `reboot` command as appropriate.

# Booting for Recovery Purposes in a ZFS Root Environment

You might need to boot the system to resolve a corrupt bootloader problem, a root password problem, or a bad shell. For the recovery procedures for each of these cases, see Shutting Down and Booting a System for Recovery Purposes in *Booting and Shutting Down Oracle Solaris 11.4 Systems* .

If you need to replace a disk in root pool, see Replacing Disks in a ZFS Root Pool. If you need to perform complete system (bare metal) recovery, see *Using Unified Archives for System Recovery and Cloning in Oracle Solaris 11.4* .

7

# Managing Oracle Solaris ZFS File Systems

This chapter provides detailed information about managing Oracle Solaris ZFS file systems. Concepts such as the hierarchical file system layout, property inheritance, and automatic mount point management and share interactions are included.

This chapter discusses the following topics:



> **Note:**
>
> The term *dataset* is used in this chapter as a generic term to refer to a file system, snapshot, clone, or volume.

## Introduction to ZFS File Systems

You build a ZFS file system on top of a storage pool. ZFS file systems can be dynamically created and destroyed without requiring you to allocate or format any underlying disk space. Because these file systems are so lightweight and because they are the central point of administration in ZFS, you are likely to create many of them.

You can administer ZFS file systems by using the `zfs` command. The `zfs` command provides a set of subcommands that perform specific operations on file systems. This chapter describes these subcommands in detail. Snapshots, clones, and volumes are also managed by using this

command, but these features are only covered briefly in this chapter. For detailed information about snapshots and clones, see Working With Oracle Solaris ZFS Snapshots and Clones. For detailed information about ZFS volumes, see ZFS Volumes.

All invocations of the `zfs` command require the name of the file system. The file system name is specified as a path name starting from the name of the pool as follows:

*pool-name*/[*dataset-path*]/*filesystem-name*

The pool name and the dataset path identify the location of the file system in the hierarchy. The last part in the name identifies the file system name. The file system name must satisfy the naming requirements in Naming ZFS Components. For example, the `tank/home/sueb` file system name would refer to a ZFS file system named `sueb`, in the `/home` dataset path, in the `tank` pool,

# Creating ZFS File Systems

This section provides steps and examples for creating ZFS file systems.

## How to Create a ZFS File System

The `zfs create` command automatically mounts the newly created file system, if it is created successfully. By default, file systems are mounted as */dataset*, using the dataset name provided with the `create` subcommand. In this example, the newly created `sueb` file system is mounted at `/tank/home/sueb`. For more information about automatically managed mount points, see Managing ZFS Mount Points.

> **Note:**
>
> Encrypting a ZFS file system must be enabled when the file system is created. For information about encrypting a ZFS file system, see Encrypting ZFS File Systems.

For more information about the `zfs create` command, see the `zfs`(8) man page.

1. **Assume the root role or an equivalent role with the appropriate ZFS rights profile.**
2. **Create the ZFS file system.**

**Example 7-1 Creating a Simple ZFS File System**

In the following example, a file system named `sueb` is created in the `tank/home` file system.

```
$ zfs create tank/home/sueb
```

**Example 7-2 Creating a ZFS File System Using File System Properties**

You can set file system properties when a file system is created. In the following example, a mount point of `/export/zfs` is created for the `tank/home` file system:

```
$ zfs create -o mountpoint=/export/zfs tank/home
```

For more information about file system properties, see Introducing ZFS Properties.

# Destroying or Renaming a ZFS File System

You can destroy a file system or dataset even if the dataset has dependent clones. Snapshots of the destroyed dataset automatically become hidden and no longer appear in the dataset listings. Being hidden, these snapshots cannot be cloned, held, or sent. Further, you cannot roll back to these snapshots.

By default, the destroy operation is performed asynchronously. The destroyed datasets are immediately reclaimed after the operation is completed and the `destroy` command returns to the caller. To perform a synchronous destroy operation, use the `-s` option when issuing the command.

## How to Destroy a ZFS File System

To destroy a ZFS file system, use the `zfs destroy` command. By default, all of the snapshots for the dataset will be destroyed. The destroyed file system is automatically unmounted and unshared. For more information about automatically managed mounts or automatically managed shares, see Automatic Mount Points.

1. **Assume the root role or an equivalent role with the appropriate ZFS rights profile.**
2. **Destroy the ZFS file system.**

   ```
   $ zfs destroy [-rRsf] filesystem
   ```

   **`-r`**
   Recursively destroys children datasets.

   **`-R`**
   Recursively destroys dependent datasets, including cloned file systems that are outside the target hierarchy.

   **`-s`**
   Performs a synchronous destroy operation where the command control does not return to the caller until the blocks occupied by the destroyed datasets are completely freed.

   **`-f`**
   Forces a file system to be unmounted in order to be destroyed.

   ***filesystem***
   Is in the format *pool-name*`/[`*dataset-path*`]/`*filesystem-name*.

   > **Caution:**
   >
   > No confirmation prompt appears with the `destroy` subcommand either by itself or with options. Use this command with extreme caution, especially when using the `-f` and `-r` options. These options can destroy large portions of the pool and consequently cause unexpected behavior for the mounted file systems that are in use.

**Example 7-3 Synchronously Destroying an Active ZFS File System**

If the file system to be destroyed is busy and cannot be unmounted, the `zfs destroy` command fails. To destroy an active file system, use the `-f` option. Use this option with caution

as it can unmount, unshare, and destroy active file systems, causing unexpected application behavior.

```
$ zfs destroy -fs tank/home/matt
```

**Example 7-4 Destroying a ZFS File System with Descendents**

The `zfs destroy` command also fails if a file system has descendents. To recursively destroy a file system and all its descendents, use the `-r` option.

```
$ zfs destroy tank/ws
cannot destroy 'tank/ws': filesystem has children
use '-r' to destroy the following datasets:
tank/ws/sueb
tank/ws/bhall
tank/ws/mork
$ zfs destroy -r tank/ws
```

## How to Rename a ZFS File System

File systems can be renamed by using the `zfs rename` command. With the `rename` subcommand, you can perform the following operations:

- Change the name of a file system.
- Relocate the file system within the ZFS hierarchy.

  The new location must be within the same pool and must have enough disk space to accommodate the new file system.

  > **Note:**
  >
  > Quota limits might become a contributing factor to insufficient disk space. See Setting ZFS Quotas.

- Change the name of a file system and relocate it within the ZFS hierarchy.

The `rename` operation attempts an unmount/remount sequence for the file system and any descendent file systems. The `rename` command fails if the operation is unable to unmount an active file system. If this problem occurs, you must forcibly unmount the file system.

1. **Assume the root role or an equivalent role with the appropriate ZFS rights profile.**
2. **Rename the ZFS file system.**

   For example, to change the name of the file system only, you would type:

   ```
   $ zfs rename tank/home/soloh tank/home/mindy_old
   ```

   To relocate a file system, you would type:

   ```
   $ zfs rename tank/home/mork tank/ws/mork
   ```

# Introducing ZFS Properties

Properties are the main mechanism that you use to control the behavior of file systems, volumes, snapshots, and clones. Unless stated otherwise, the properties defined in this section apply to all the dataset types.

Properties are divided into two types, native properties and user-defined properties. Native properties either provide internal statistics or control ZFS file system behavior. In addition, native properties are either settable or read-only. User properties have no effect on ZFS file system behavior, but you can use them to annotate datasets in a way that is meaningful in your environment. For more information about user properties, see ZFS User Properties.

Most settable properties are also inheritable. An inheritable property is a property that, when set on a parent file system, is propagated down to all of its descendents.

All inheritable properties have an associated source that indicates how a property was obtained. The source of a property can have the following values:

**`local`**
Indicates that the property was explicitly set on the dataset by using the `zfs set` command as described in Setting ZFS Properties.

**`inherited from`** ***dataset-name***
Indicates that the property was inherited from the named ancestor.

**`default`**
Indicates that the property value was not inherited or set locally. This source is a result of no ancestor having the property set as source `local`.

The following table identifies both read-only and settable native ZFS file system properties. Read-only native properties are identified as such. All other native properties listed in this table are settable. For information about user properties, see ZFS User Properties.

**Table 7-1 ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| `aclinherit` | String | `secure` | Controls how ACL entries are inherited when files and directories are created. The values are `discard`, `noallow`, `passthrough`, `passthrough-mode-preserve`, `passthrough-x`, `restricted`, and `secure`. For a description of these values, see ACL Properties in *Securing Files and Verifying File Integrity in Oracle Solaris 11.4* . |
| `aclmode` | String | `discard` | Controls how an ACL entry is modified during a `chmod` operation. The values are `discard`, `mask`, and `passthrough`. For a description of these values, see ACL Properties in *Securing Files and Verifying File Integrity in Oracle Solaris 11.4* . |
| `atime` | Boolean | `on` | Controls whether the access time for files is updated when they are read. Turning this property off avoids producing write traffic when reading files and can result in significant performance gains, though it might confuse mailers and similar utilities. |
| `available` | Number | N/A | Read-only property that identifies the amount of disk space available to a file system and all its children, assuming no other activity in the pool. Because disk space is shared within a pool, available space can be limited by various factors including physical pool size, quotas, reservations, and other datasets within the pool.<br>The property abbreviation is `avail`. |

**Table 7-1 (Cont.) ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| canmount | Boolean | on | Controls whether a file system can be mounted with the zfs mount command. This property can be set on any file system, and the property itself is not inheritable. However, when this property is set to off, a mount point can be inherited to descendent file systems, but the file system itself is never mounted.<br>When the noauto option is set, a file system can only be mounted and unmounted explicitly. The file system is not mounted automatically when the file system is created or imported, nor is it mounted by the zfs mount -a command or unmounted by the zfs unmount -a command.<br>For more information, see The canmount Property. |
| casesensitivity | String | mixed | This property indicates whether the file name matching algorithm used by the file system should be casesensitive, caseinsensitive, or allow a combination of both styles of matching (mixed). Traditionally, UNIX and POSIX file systems have case-sensitive file names.<br>The mixed value for this property indicates the file system can support requests for both case-sensitive and case-insensitive matching behavior. Currently, case-insensitive matching behavior on a file system that supports mixed behavior is limited to the Oracle Solaris SMB server product. For more information about using the mixed value, see The casesensitivity Property.<br>Regardless of the casesensitivity property setting, the file system preserves the case of the name specified to create a file. This property cannot be changed after the file system is created. |
| checksum | String | on | Controls the checksum used to verify data integrity. The default value is on, which automatically selects an appropriate algorithm, currently fletcher4. The values are on, off, fletcher2, fletcher4, sha256, sha3-256, and sha256+mac. A value of off disables integrity checking on user data. A value of off is not recommended. |
| compression | String | off | Enables or disables compression for a dataset. The values are on, off, lzjb, lz4, gzip, and gzip- *N*. Currently, setting this property to lzjb, gzip, or gzip- *N* has the same effect as setting this property to on. Enabling compression on a file system with existing data only compresses new data. Existing data remains uncompressed.<br>The property abbreviation is compress. |
| compressratio | Number | N/A | Read-only property that identifies the compression ratio achieved for a dataset, expressed as a multiplier. Compression can be enabled by the zfs set compression=on *dataset* command.<br>The value is calculated from the logical size of all files and the amount of referenced physical data. It includes explicit savings through the use of the compression property. |
| copies | Number | 1 | Sets the number of copies of user data per file system. Available values are 1, 2, or 3. These copies are in addition to any pool-level redundancy. Disk space used by multiple copies of user data is charged to the corresponding file and dataset, and counts against quotas and reservations. In addition, the used property is updated when multiple copies are enabled. Consider setting this property when the file system is created because changing this property on an existing file system only affects newly written data. |
| creation | String | N/A | Read-only property that identifies the date and time that a dataset was created. |

**Table 7-1 (Cont.) ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| dedup | String | off | Controls the ability to remove duplicate data in a ZFS file system. Possible values are on, off, verify, and sha256[,verify]. The default checksum for deduplication is sha256.<br>For more information, see The dedup Property. |
| defaultgroupquota | String | None | Sets a default group quota. The value applies to all groups who do not have an explicit group quota specified. The default value is none. For more information, see Setting Default User and Group Quotas. |
| defaultuserquota | String | None | Sets a default user quota. The value applies to all users who do not have an explicit user quota specified. The default value is none. For more information, see Setting Default User and Group Quotas. |
| devices | Boolean | on | Controls whether device files in a file system can be opened. |
| encryption | Boolean | off | Controls whether a file system is encrypted. An encrypted file system means that data is encoded and a key is needed by the file system owner to access the data. |
| exec | Boolean | on | Controls whether programs in a file system are allowed to be executed. Also, when set to off, mmap(2) calls with PROT_EXEC are disallowed. |
| keychangedate | String | none | Read-only property that identifies the date of the last wrapping key change from a zfs key -c operation for the specified file system. If no key change operation has occurred, the value of this property is the same as the file system's creation date. |
| keysource | String | none | Identifies the format and location of the key that wraps the file system keys. The valid property values are raw, hex, passphrase,prompt, or *file*. The key must be present when the file system is created, mounted, or loaded by using the zfs key -l command. If encryption is enabled for a new file system, the default keysource is passphrase,prompt. |
| keystatus | String | none | Read-only property that identifies the file system's encryption key status. The availability of a file system's key is indicated by available or unavailable. For file systems that do not have encryption enabled, none is displayed. |
| logbias | String | latency | Controls how ZFS optimizes synchronous requests for this file system. If logbias is set to latency, ZFS uses the pool's separate log devices, if any, to handle the requests at low latency. If logbias is set to throughput, ZFS does not use the pool's separate log devices. Instead, ZFS optimizes synchronous operations for global pool throughput and efficient use of resources. The default value is latency. |
| mlslabel | String | None | Provides a sensitivity label that determines if a file system can be mounted in a zone. If the labeled file system matches the labeled zone, the file system can be mounted and accessed from the labeled zone. The default value is none. This property can only be modified with the appropriate privilege.<br>The behavior of the mlslabel property changes depending if Trusted Extensions is enabled or if the multilevel property is set. See The mlslabel Property for more information. |
| mounted | Boolean | N/A | Read-only property that indicates whether a file system, clone, or snapshot is currently mounted. This property does not apply to volumes. The value can be either yes or no. |

**Table 7-1 (Cont.) ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| `mountpoint` | String | N/A | Controls the mount point used for this file system. When the `mountpoint` property is changed for a file system, the file system and any descendents that inherit the mount point are unmounted. If the new value is `legacy`, then they remain unmounted. Otherwise, they are automatically remounted in the new location if the property was previously `legacy` or `none`, or if they were mounted before the property was changed. In addition, any shared file systems are unshared and shared in the new location.<br>For more information about using this property, see Managing ZFS Mount Points. |
| `multilevel` | Boolean | `off` | The `multilevel` property is used to enable the use of labels on the objects in a ZFS file system. Objects in a multilevel file system are individually labeled with an explicit sensitivity label attribute that is automatically generated. Objects can be relabeled in place by changing this label attribute, by using the `setlabel` or `setflabel` commands.<br>A root file system, an Oracle Solaris Zone file system, or a file system that contains packaged Oracle Solaris code should not be multilevel.<br>See The mlslabel Property for more information. |
| `nbmand` | Boolean | `off` | Controls whether the file system should be mounted with `nbmand` (Non-blocking mandatory) locks. This property is for SMB clients only. Changes to this property only take effect when the file system is unmounted and remounted. |
| `normalization` | String | None | This property indicates whether a file system should perform a unicode normalization of file names whenever two file names are compared, and which normalization algorithm should be used. File names are always stored unmodified, names are normalized as part of any comparison process. If this property is set to a legal value other than `none`, and the `utf8only` property was left unspecified, the `utf8only` property is automatically set to `on`. The default value of the `normalization` property is `none`. This property cannot be changed after the file system is created. |
| `origin` | String | N/A | Read-only property for cloned file systems or volumes that identifies the snapshot from which the clone was created. The origin cannot be destroyed (even with the `-r` or `-f` option) as long as a clone exists.<br>Non-cloned file systems have an origin of `none`. |
| `primarycache` | String | `all` | Controls what is cached in the primary cache (ARC). Possible values are `all`, `none`, and `metadata`. If set to `all`, both user data and metadata are cached. If set to `none`, neither user data nor metadata is cached. If set to `metadata`, only metadata is cached. When these properties are set on existing file systems, only new I/O is cache based on the values of these properties. Some database environments might benefit from not caching user data. You must determine if setting cache properties is appropriate for your environment. |
| `quota` | Number (or `none`) | `none` | Limits the amount of disk space a file system and its descendents can consume. This property enforces a hard limit on the amount of disk space used, including all space consumed by descendents, such as file systems and snapshots. Setting a quota on a descendent of a file system that already has a quota does not override the ancestor's quota, but rather imposes an additional limit. Quotas cannot be set on volumes, as the `volsize` property acts as an implicit quota.<br>For information about setting quotas, see Setting Quotas on ZFS File Systems. |

**Table 7-1 (Cont.) ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| readonly | Boolean | off | Controls whether a dataset can be modified. When set to on, no modifications can be made.<br>The property abbreviation is rdonly. |
| recordsize | Number | 128K | Specifies a suggested block size for files in a file system.<br>The property abbreviation is recsize. For a detailed description, see The recordsize Property. |
| referenced | Number | N/A | Read-only property that identifies the amount of data accessible by a dataset, which might or might not be shared with other datasets in the pool.<br>When a snapshot or clone is created, it initially references the same amount of disk space as the file system or snapshot it was created from, because its contents are identical.<br>The property abbreviation is refer. |
| refquota | Number (or none) | none | Sets the amount of disk space that a dataset can consume. This property enforces a hard limit on the amount of space used. This hard limit does not include disk space used by descendents, such as snapshots and clones. |
| refreservation | Number (or none) | none | Sets the minimum amount of disk space that is guaranteed to a dataset, not including descendents, such as snapshots and clones. When the amount of disk space used is below this value, the dataset is treated as if it were taking up the amount of space specified by refreservation. The refreservation reservation is accounted for in the parent dataset's disk space used, and counts against the parent dataset's quotas and reservations.<br>If refreservation is set, a snapshot is only allowed if enough free pool space is available outside of this reservation to accommodate the current number of *referenced* bytes in the dataset.<br>The property abbreviation is refreserv. |
| rekeydate | String | N/A | Read-only property that indicates the date of the last data encryption key change from a zfs key -K or zfs clone -K operation on this file system. If no rekey operation has been performed, the value of this property is the same as the creation date. |
| reservation | Number (or none) | none | Sets the minimum amount of disk space guaranteed to a file system and its descendents. When the amount of disk space used is below this value, the file system is treated as if it were using the amount of space specified by its reservation. Reservations are accounted for in the parent file system's disk space used, and count against the parent file system's quotas and reservations.<br>The property abbreviation is reserv.<br>For more information, see Setting Reservations on ZFS File Systems. |
| rstchown | Boolean | on | Indicates whether the file system owner can grant file ownership changes. The default is to restrict chown operations. When rstchown is set to off, the user has the PRIV_FILE_CHOWN_SELF privilege for chown operations. |
| secondarycache | String | all | Controls what is cached in the secondary cache (L2ARC). Possible values are all, none, and metadata. If set to all, both user data and metadata are cached. If set to none, neither user data nor metadata is cached. If set to metadata, only metadata is cached. |
| setuid | Boolean | on | Controls whether the setuid bit is honored in a file system. |

**Table 7-1 (Cont.) ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| `shadow` | String | `None` | Identifies a ZFS file system as a *shadow* of the file system described by the *URI*. Data is migrated to a shadow file system with this property set from the file system identified by the URI. The file system to be migrated must be read-only for a complete migration. |
| `share.nfs` | String | `off` | Controls whether an NFS share of a ZFS file system is created and published and what options are used. You can also publish and unpublish an NFS share by using the `zfs share` and `zfs unshare` commands. Using the `zfs share` command to publish an NFS share requires that an NFS share property is also set. For information about setting NFS share properties, see Sharing and Unsharing ZFS File Systems.<br>For more information about sharing ZFS file systems, see Sharing and Unsharing ZFS File Systems. |
| `share.smb` | String | `off` | Controls whether a SMB share of a ZFS file system is created and published and what options are used. You can also publish and unpublish an SMB share by using the `zfs share` and `zfs unshare` commands. Using the `zfs share` command to publish an SMB share require that an SMB share property is also set. For information about setting SMB share properties, see Sharing and Unsharing ZFS File Systems. |
| `snapdir` | String | `hidden` | Controls whether the `.zfs` directory is hidden or visible in the root of the file system. For more information about using snapshots, see Overview of ZFS Snapshots. |
| `sync` | String | `standard` | Determines the synchronous behavior of a file system's transactions. Possible values are:<br>• `standard`, the default value, which means synchronous file system transactions, such as `fsync`, `O_DSYNC`, `O_SYNC`, and so on, are written to the intent log.<br>• `always`, ensures that *every* file system transaction is written and flushed to stable storage by a returning system call. This value has a significant performance penalty.<br>• `disabled`, means that synchronous requests are disabled. File system transactions are only committed to stable storage on the next transaction group commit, which might be after many seconds. This value gives the best performance, with no risk of corrupting the pool.<br>**Caution:**<br>This `disabled` value is very dangerous because ZFS is ignoring the synchronous transaction demands of applications, such as databases or NFS operations. Setting this value on the currently active root or `/var` file system might result in unexpected behavior, application data loss, or increased vulnerability to replay attacks. You should only use this value if you fully understand all the associated risks. |
| `type` | String | N/A | Read-only property that identifies the dataset type as `filesystem` (file system or clone), `volume`, or `snapshot`. |
| `used` | Number | N/A | Read-only property that identifies the amount of disk space consumed by a dataset and all its descendents.<br>For a detailed description, see ZFS Read-Only Native Properties. |

**Table 7-1 (Cont.) ZFS Native Property Descriptions**

| Property Name | Type | Default Value | Description |
|---|---|---|---|
| usedbychildren | Number | off | Read-only property that identifies the amount of disk space that is used by children of this dataset, which would be freed if all the dataset's children were destroyed. The property abbreviation is usedchild. |
| usedbydataset | Number | off | Read-only property that identifies the amount of disk space that is used by a dataset itself, which would be freed if the dataset was destroyed, after first destroying any snapshots and removing any refreservation reservations. The property abbreviation is usedds. |
| usedbyrefreservation | Number | off | Read-only property that identifies the amount of disk space that is used by a refreservation set on a dataset, which would be freed if the refreservation was removed. The property abbreviation is usedrefreserv. |
| usedbysnapshots | Number | off | Read-only property that identifies the amount of disk space that is consumed by snapshots of a dataset. In particular, it is the amount of disk space that would be freed if all of this dataset's snapshots were destroyed. Note that this value is not simply the sum of the snapshots' used properties, because space can be shared by multiple snapshots. The property abbreviation is usedsnap. |
| utf8only | Boolean | Off | This property indicates whether a file system should reject file names that include characters that are not present in the UTF-8 character code set. If this property is explicitly set to off, the normalization property must either not be explicitly set or be set to none. The default value for the utf8only property is off. This property cannot be changed after the file system is created. |
| version | Number | N/A | Identifies the on-disk version of a file system, which is independent of the pool version. This property can only be set to a later version that is available from the supported software release. For more information, see the zfs upgrade command. |
| volblocksize | Number | 8 KB | For volumes, specifies the block size of the volume. The block size cannot be changed after the volume has been written, so set the block size at volume creation time. The default block size for volumes is 8 KB. Any power of 2 from 512 bytes to 128 KB is valid.<br>The property abbreviation is volblock. |
| volsize | Number | N/A | For volumes, specifies the logical size of the volume.<br>For a detailed description, see The volsize Property. |
| vscan | Boolean | Off | Controls whether regular files should be scanned for viruses when a file is opened and closed. In addition to enabling this property, a virus scanning service must also be enabled for virus scanning to occur if you have third-party virus scanning software. The default value is off. |
| xattr | Boolean | on | Indicates whether extended attributes are enabled (on) or disabled (off) for this file system. |
| zoned | Boolean | N/A | Indicates whether a file system has been added to a non-global zone. If this property is set, then the mount point is not honored in the global zone, and ZFS cannot mount such a file system when requested. When a zone is first installed, this property is set for any added file systems.<br>For more information about using ZFS with zones installed, see Using ZFS on an Oracle Solaris System With Zones Installed. |

# ZFS Read-Only Native Properties

Read-only native properties can be retrieved but not set. Read-only native properties are not inherited. Some native properties are specific to a particular type of dataset. In such cases, the dataset type is mentioned in the description in ZFS Native Property Descriptions.

The `used` property is an example of a read-only property. This property identifies the amount of disk space consumed by this dataset and all its descendents. This value is checked against the dataset's quota and reservation. The disk space used does not include the dataset's reservation, but does consider the reservation of any descendent datasets. The amount of disk space that a dataset consumes from its parent, as well as the amount of disk space that is freed if the dataset is recursively destroyed, is the greater of its space used and its reservation.

When snapshots are created, their disk space is initially shared between the snapshot and the file system, and possibly with previous snapshots. As the file system changes, disk space that was previously shared becomes unique to the snapshot and is counted in the snapshot's space used. The disk space that is used by a snapshot accounts for its unique data. Additionally, deleting snapshots can increase the amount of disk space unique to (and used by) other snapshots.

The amount of disk space used, available, and referenced does not include pending changes. Pending changes are generally accounted for within a few seconds. Committing a change to a disk using the `fsync(3c)` or `O_SYNC` function does not necessarily guarantee that the disk space usage information will be updated immediately.

The `usedbychildren`, `usedbydataset`, `usedbyrefreservation`, and `usedbysnapshots` property information can be displayed with the `zfs list -o space` command. These properties identify the `used` property into disk space that is consumed by descendents. For more information, see ZFS Native Property Descriptions.

# Settable ZFS Native Properties

Settable native properties are properties whose values can be both retrieved and set. Settable native properties are set by using the `zfs set` command, as described in Setting ZFS Properties or by using the `zfs create` command as described in How to Create a ZFS File System. With the exceptions of quotas and reservations, settable native properties are inherited. For more information about quotas and reservations, see Setting ZFS Quotas.

Some settable native properties are specific to a particular type of dataset. In such cases, the dataset type is mentioned in the description in ZFS Native Property Descriptions. If not specifically mentioned, a property applies to all dataset types: file systems, volumes, clones, and snapshots.

## The `canmount` Property

If the `canmount` property is set to `off`, the file system cannot be mounted by using the `zfs mount` or `zfs mount -a` commands. Setting this property to `off` is similar to setting the `mountpoint` property to `none`, except that the file system still has a normal `mountpoint` property that can be inherited. For example, you can set this property to `off`, establish inheritable properties for descendent file systems, but the parent file system itself is never mounted nor is it accessible to users. In this case, the parent file system is serving as a *container* so that you can set properties on the container, but the container itself is never accessible.

In the following example, `userpool` is created, and its `canmount` property is set to `off`. Mount points for descendent user file systems are set to one common mount point, `/export/home`.

Properties that are set on the parent file system are inherited by descendent file systems, but the parent file system itself is never mounted.

```
$ zpool create userpool mirror c0t5d0 c1t6d0
$ zfs set canmount=off userpool
$ zfs set mountpoint=/export/home userpool
$ zfs set compression=on userpool
$ zfs create userpool/user1
$ zfs create userpool/user2
$ zfs mount
userpool/user1                  /export/home/user1
userpool/user2                  /export/home/user2
```

Setting the `canmount` property to `noauto` means that the file system can only be mounted explicitly, not automatically.

## The `casesensitivity` Property

This property indicates whether the file name matching algorithm used by the file system should be `casesensitive`, `caseinsensitive`, or allow a combination of both styles of matching (`mixed`).

When a case-insensitive matching request is made of a *mixed* sensitivity file system, the behavior is generally the same as would be expected of a purely case-insensitive file system. The difference is that a mixed sensitivity file system might contain directories with multiple names that are unique from a case-sensitive perspective, but not unique from the case-insensitive perspective.

For example, a directory might contain files `foo`, `Foo`, and `FOO`. If a request is made to case-insensitively match any of the possible forms of `foo`, (for example `foo`, `FOO`, `FoO`, `fOo`, and so on) one of the three existing files is chosen as the match by the matching algorithm. Exactly which file the algorithm chooses as a match is not guaranteed, but what is guaranteed is that the same file is chosen as a match for any of the forms of `foo`. The file chosen as a case-insensitive match for `foo`, `FOO`, `foO`, `Foo`, and so on, is always the same, so long as the directory remains unchanged.

The `utf8only`, `normalization`, and `casesensitivity` properties also provide new permissions that can be assigned to non-privileged users by using ZFS delegated administration. For more information, see Delegating ZFS Permissions.

## The `copies` Property

As a reliability feature, ZFS file system metadata is automatically stored multiple times across different disks, if possible. This feature is known as *ditto blocks*.

In this release, you can also store multiple copies of user data is also stored per file system by using the `zfs set copies` command. For example:

```
$ zfs set copies=2 users/home
$ zfs get copies users/home
NAME        PROPERTY  VALUE       SOURCE
users/home  copies    2           local
```

Available values are 1, 2, or 3. The default value is 1. These copies are in addition to any pool-level redundancy, such as in a mirrored or RAID-Z configuration.

The benefits of storing multiple copies of ZFS user data are as follows:

- Improves data retention by enabling recovery from unrecoverable block read faults, such as media faults (commonly known as *bit rot*) for all ZFS configurations.
- Provides data protection, even when only a single disk is available.
- Enables you to select data protection policies on a per-file system basis, beyond the capabilities of the storage pool.

> **Note:**
>
> Depending on the allocation of the ditto blocks in the storage pool, multiple copies might be placed on a single disk. A subsequent full disk failure might cause all ditto blocks to be unavailable.

You might consider using ditto blocks when you accidentally create a non-redundant pool and when you need to set data retention policies.

## The `dedup` Property

The `dedup` property controls whether duplicate data is removed from a file system. If a file system has the `dedup` property enabled, duplicate data blocks are removed synchronously. The result is that only unique data is stored and common components are shared between files.

Do not enable the `dedup` property on file systems that reside on production systems until you review the following considerations:

1. Determine if your data would benefit from deduplication space savings. You can run the `zdb -S` command to simulate the potential space savings of enabling dedup on your pool. This command must be run on a quiet pool. If your data is not dedup-able, then there's not point in enabling dedup. For example:

```
$ zdb -S tank
Simulated DDT histogram:
bucket              allocated                       referenced
______   ______________________________   ______________________________
refcnt   blocks   LSIZE   PSIZE   DSIZE   blocks   LSIZE   PSIZE   DSIZE
------   ------   -----   -----   -----   ------   -----   -----   -----
1         2.27M    239G    188G    194G    2.27M    239G    188G    194G
2          327K   34.3G   27.8G   28.1G     698K   73.3G   59.2G   59.9G
4         30.1K   2.91G   2.10G   2.11G     152K   14.9G   10.6G   10.6G
8         7.73K    691M    529M    529M    74.5K   6.25G   4.79G   4.80G
16          673   43.7M   25.8M   25.9M    13.1K    822M    492M    494M
32          197   12.3M   7.02M   7.03M    7.66K    480M    269M    270M
64           47   1.27M    626K    626K    3.86K    103M   51.2M   51.2M
128          22    908K    250K    251K    3.71K    150M   40.3M   40.3M
256           7    302K     48K   53.7K    2.27K   88.6M   17.3M   19.5M
512           4    131K   7.50K   7.75K    2.74K    102M   5.62M   5.79M
2K            1      2K      2K      2K    3.23K   6.47M   6.47M   6.47M
8K            1    128K      5K      5K    13.9K   1.74G   69.5M   69.5M
Total     2.63M    277G    218G    225G    3.22M    337G    263G    270G

dedup = 1.20, compress = 1.28, copies = 1.03, dedup * compress / copies = 1.50
```

   If the estimated dedup ratio is greater than 2, then you might see dedup space savings.

   In the above example, the dedup ratio is less than 2, so enabling dedup is not recommended.

2. Make sure your system has enough memory to support dedup.

- Each in-core dedup table entry is approximately 320 bytes
- Multiply the number of allocated blocks times 320. For example:

```
in-core DDT size = 2.63M x 320 = 841.60M
```

3. Dedup performance is best when the deduplication table fits into memory. If the dedup table has to be written to disk, then performance will decrease. For example, removing a large file system with dedup enabled will severely decrease system performance if the system does not meet the memory requirements described above.
4. You cannot use deduplication in the case of datasets with encryption. For example, a filesystem and a volume are two different datasets and deduplication cannot match the two together.

When `dedup` is enabled, the `dedup` checksum algorithm overrides the `checksum` property. Setting the property value to `verify` is equivalent to specifying `sha256,verify`. If the property is set to `verify` and two blocks have the same signature, ZFS does a byte-by-byte comparison with the existing block to ensure that the contents are identical.

This property can be enabled per file system. For example:

```
$ zfs set dedup=on tank/home
```

You can use the `zfs get` command to determine if the `dedup` property is set.

Although deduplication is set as a file system property, the scope is pool-wide. For example, you can identify the deduplication ratio. For example:

```
$ zpool list tank
NAME    SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
rpool   136G  55.2G  80.8G    40%  2.30x  ONLINE  -
```

The `DEDUP` column indicates how much deduplication has occurred. If the `dedup` property is not enabled on any file system or if the `dedup` property was just enabled on the file system, the `DEDUP` ratio is `1.00x`.

You can use the `zpool get` command to determine the value of the `dedupratio` property. For example:

```
$ zpool get dedupratio export
NAME   PROPERTY    VALUE  SOURCE
rpool  dedupratio  3.00x  -
```

This pool property illustrates how much data deduplication this pool has achieved.

## The `encryption` Property

You can use the encryption property to encrypt ZFS file systems. For more information, see Encrypting ZFS File Systems.

## The `mlslabel` Property

The behavior of the `mlslabel` property changes depending if Trusted Extensions is enabled or if the `multilevel` property is set.

If Trusted Extensions is not enabled, then the `mlslabel` has no meaning unless the `multilevel` property is also set. If both properties are set, the `mlslabel` property is automatically updated so that it is the maximum label of all files that have been explicitly labeled in the file system. In this configuration, the `mlslabel` property cannot be set by an administrator and cannot be lowered.

When Trusted Extensions is enabled, the `mlslabel` property should be set by an administrator. For single-level file systems, that is when the `multilevel` property is not set, the `mlslabel` property specifies the label of the zone in which the file system can be mounted. If the `mlslabel` property value matches the labeled zone, the file system can be mounted and accessed from the labeled zone.

If the `multilevel` property is set, the `mlslabel` property specifies the maximum label that can be set on any file in the file system. An attempt to create a file at (or relabel a file to) a label higher than the `mlslabel` property value is not allowed. Mount policy based on the `mlslabel` property does not apply to a multilevel file system.

Also, for a multilevel file system, the `mlslabel` property can be set explicitly when the file system is created. Otherwise, a default `mlslabel` property of `ADMIN_HIGH` is automatically created. After creating a multilevel file system, the `mlslabel` property can be changed, but it cannot be set to a lower label, it cannot not be set to `none`, nor can it be removed.

When Trusted Extensions is enabled, the automatic label that is applied to newly created objects is the label of the zone in which the caller is executing, and the maximum label that can be set explicitly is the label of the zone. If Trusted Extensions is not enabled, the automatic label of newly created objects is the label of their parent directory, and the maximum label is the label corresponding to the caller's clearance.

## The `multilevel` Property

The `multilevel` property is used to enable the use of labels on the objects in a ZFS file system. Objects in a multilevel file system are individually labeled with an explicit sensitivity label attribute that is automatically generated. Objects can be relabeled in place by changing this label attribute, by using the `setlabel` or `setflabel` commands.

A root file system, an Oracle Solaris Zone file system, or a file system that contains packaged Oracle Solaris code should not be multilevel.

## The `recordsize` Property

The `recordsize` property specifies a suggested block size for files in the file system.

This property is designed solely for use with database workloads that access files in fixed-size records. ZFS automatically adjust block sizes according to internal algorithms optimized for typical access patterns. For databases that create very large files but access the files in small random chunks, these algorithms might be suboptimal. Specifying a `recordsize` value greater than or equal to the record size of the database can result in significant performance gains. Use of this property for general purpose file systems is strongly discouraged and might adversely affect performance. The size specified must be a power of 2 greater than or equal to 512 bytes and less than or equal to 1 MB. Changing the file system's `recordsize` value only affects files created afterward. Existing files are unaffected.

The property abbreviation is `recsize`.

## The `share.smb` Property

This property enables sharing of ZFS file systems with the Oracle Solaris SMB service, and identifies options to be used.

When the property is changed from off to on, any shares that inherit the property are re-shared with their current options. When the property is set to off, the shares that inherit the property are unshared.For examples of using the `share.smb` property, see Sharing and Unsharing ZFS File Systems.

## The `volsize` Property

The `volsize` property specifies the logical size of the volume. By default, creating a volume establishes a reservation for the same amount. Any changes to `volsize` are reflected in an equivalent change to the reservation. These checks are used to prevent unexpected behavior for users. A volume that contains less space than it claims is available can result in undefined behavior or data corruption, depending on how the volume is used. These effects can also occur when the volume size is changed while the volume is in use, particularly when you shrink the size. Use extreme care when adjusting the volume size.

For more information about using volumes, see ZFS Volumes.

# ZFS User Properties

In addition to the native properties, ZFS supports arbitrary user properties. User properties have no effect on ZFS behavior, but you can use them to annotate datasets with information that is meaningful in your environment.

User property names must conform to the following conventions:

- They must contain a colon (':') character to distinguish them from native properties.
- They must contain lowercase letters, numbers, or the following punctuation characters: ':', '+','.', '_'.
- The maximum length of a user property name is 256 characters.

The expected convention is that the property name is divided into the following two components but this namespace is not enforced by ZFS:

*module*:*property*

When making programmatic use of user properties, use a reversed DNS domain name for the *module* component of property names to reduce the chance that two independently developed packages will use the same property name for different purposes. Property names that begin with `com.oracle.` are reserved for use by Oracle Corporation.

The values of user properties must conform to the following conventions:

- They must consist of arbitrary strings that are always inherited and are never validated.
- The maximum length of the user property value is 1024 characters.

For example:

```
$ zfs set dept:users=finance userpool/user1
$ zfs set dept:users=general userpool/user2
$ zfs set dept:users=itops userpool/user3
```

All of the commands that operate on properties, such as `zfs list`, `zfs get`, `zfs set`, and so on, can be used to manipulate both native properties and user properties.

For example:

```
zfs get -r dept:users userpool
NAME            PROPERTY    VALUE           SOURCE
userpool        dept:users  all             local
userpool/user1  dept:users  finance         local
```

```
userpool/user2  dept:users  general         local
userpool/user3  dept:users  itops           local
```

To clear a user property, use the `zfs inherit` command. For example:

```
$ zfs inherit -r dept:users userpool
```

If the property is not defined in any parent dataset, it is removed entirely.

# Querying ZFS File System Information

The `zfs list` command provides an extensible mechanism for viewing and querying dataset information. Both basic and complex queries are explained in this section.

## Listing Basic ZFS Information

You can list basic dataset information by using the `zfs list` command with no options. This command displays the names of all datasets on the system and the values of their `used`, `available`, `referenced`, and `mountpoint` properties. For more information about these properties, see Introducing ZFS Properties.

For example:

```
$ zfs list
users                  2.00G  64.9G    32K  /users
users/home             2.00G  64.9G    35K  /users/home
users/home/kaydo        548K  64.9G   548K  /users/home/kaydo
users/home/mork        1.00G  64.9G  1.00G  /users/home/mork
users/home/nneke       1.00G  64.9G  1.00G  /users/home/nneke
```

You can also use this command to display specific datasets by providing the dataset name on the command line. Additionally, use the `-r` option to recursively display all descendents of that dataset. For example:

```
$ zfs list -t all -r users/home/mork
NAME                        USED  AVAIL  REFER  MOUNTPOINT
users/home/mork            1.00G  64.9G  1.00G  /users/home/mork
users/home/mork@yesterday      0      -  1.00G  -
users/home/mork@today          0      -  1.00G  -
```

You can use the `zfs list` command with the mount point of a file system. For example:

```
$ zfs list /user/home/mork
NAME             USED  AVAIL  REFER  MOUNTPOINT
users/home/mork  1.00G  64.9G  1.00G  /users/home/mork
```

The following example shows how to display basic information about `tank/home/gina` and all of its descendent file systems:

```
$ zfs list -r users/home/gina
NAME                          USED  AVAIL  REFER  MOUNTPOINT
users/home/gina              2.00G  62.9G    32K  /users/home/gina
users/home/gina/projects     2.00G  62.9G    33K  /users/home/gina/projects
users/home/gina/projects/fs1 1.00G  62.9G  1.00G  /users/home/gina/projects/fs1
users/home/gina/projects/fs2 1.00G  62.9G  1.00G  /users/home/gina/projects/fs2
```

For additional information about the `zfs list` command, see the see `zfs`(8) man page.

# Creating Complex ZFS Queries

The `zfs list` output can be customized by using the `-o`, `-t`, and `-H` options.

You can customize property value output by using the `-o` option and a comma-separated list of desired properties. You can supply any dataset property as a valid argument. For a list of all supported dataset properties, see Introducing ZFS Properties. In addition to the properties defined, the `-o` option list can also contain the literal `name` to indicate that the output should include the name of the dataset.

The following example uses `zfs list` to display the dataset name, along with the `share.nfs` and `mountpoint` property values.

```
$ zfs list -r -o name,share.nfs,mountpoint users/home
NAME                          NFS       MOUNTPOINT
users/home                    on        /users/home
users/home/kaydo              on        /users/home/kaydo
users/home/gina               on        /users/home/gina
users/home/gina/projects      on        /users/home/gina/projects
users/home/gina/projects/fs1  on        /users/home/gina/projects/fs1
users/home/gina/projects/fs2  on        /users/home/gina/projects/fs2
users/home/mork               on        /users/home/mork
users/home/nneke               on        /users/home/nneke
```

You can use the `-t` option to specify the types of datasets to display. The valid types are:

```
filesystem
share
snapshot
volume
```

The `-t` options takes a comma-separated list of the types of datasets to be displayed. The following example uses the `-t` and `-o` options simultaneously to show the name and `used` property for all file systems:

```
$ zfs list -r -t filesystem -o name,used users/home
NAME                          USED
users/home                   4.00G
users/home/kaydo              548K
users/home/gina              2.00G
users/home/gina/projects     2.00G
users/home/gina/projects/fs1 1.00G
users/home/gina/projects/fs2 1.00G
users/home/mork              1.00G
users/home/nneke              1.00G
```

You can use the `-H` option to omit the `zfs list` header from the generated output. With the `-H` option, all white space is replaced by the Tab character. This option can be useful when you need parseable output, for example, when scripting. The following example shows the output generated from using the `zfs list` command with the `-H` option:

```
$ zfs list -r -H -o name users/home
users/home
users/home/kaydo
users/home/gina
users/home/gina/projects
users/home/gina/projects/fs1
users/home/gina/projects/fs2
```

```
users/home/mork
users/home/nneke
```

## Listing Incomplete ZFS Datasets

An incomplete dataset is created when a dataset transfer started by running `zfs receive` is interrupted. The `zfs list -I` command can be used to show which datasets are incomplete. The state for each dataset can be either receiving or resumable. Arguments with the `-I` option are all, resumable or receiving.

```
$ zfs list -I all
NAME            USED  AVAIL  REFER  TYPE    STATE
users/home/dst  189M   910G   189M  volume  resumable
```

You can use the following command to show just the names of the resumable datasets,

```
$ zfs list -HI resumable
users/home/dst
```

## Creating Parsable Output with `zfs list`

The `zfs list -o` command can be used with the `-p` option to create exact machine-parsable numeric output. For example:

```
$ zfs list -o guid users/home
GUID
3.30E
$ zfs list -po guid users/home
GUID
3807001345661527925
```

# Managing ZFS Properties

Dataset properties are managed through the `zfs` command's `set`, `inherit`, and `get` subcommands.

## Setting ZFS Properties

You can use the `zfs set` command to modify any settable dataset property. Or, you can use the `zfs create` command to set properties when a dataset is created. For a list of settable dataset properties, see Settable ZFS Native Properties.

The `zfs set` command takes a property/value sequence in the format of *property=value* followed by a dataset name. Only one property can be set or modified during each `zfs set` invocation.

The following example sets the `atime` property to `off` for `tank/home`.

```
$ zfs set atime=off tank/home
```

In addition, any file system property can be set when a file system is created. For example:

```
$ zfs create -o atime=off tank/home
```

You can specify numeric property values by using the following easy-to-understand suffixes (in increasing sizes): `BKMGTPEZ`. Any of these suffixes can be followed by an optional `b`, indicating bytes, with the exception of the `B` suffix, which already indicates bytes. The following four

invocations of `zfs set` are equivalent numeric expressions that set the `quota` property be set to the value of 20GB on the `users/home/mork` file system:

```
$ zfs set quota=20G users/home/mork
$ zfs set quota=20g users/home/mork
$ zfs set quota=20GB users/home/mork
$ zfs set quota=20gb users/home/mork
```

If you attempt to set a property on a file system that is 100% full, you will see a message similar to the following:

```
$ zfs set quota=20gb users/home/mork
cannot set property for '/users/home/mork': out of space
```

The values of non-numeric properties are case-sensitive and must be in lowercase letters, with the exception of `mountpoint`. The values of this property can have mixed upper and lower case letters.

For more information about the `zfs set` command, see the `zfs`(8) man page.

# Inheriting ZFS Properties

All settable properties, with the exception of quotas and reservations, inherit their value from the parent file system, unless a quota or reservation is explicitly set on the descendent file system. If no ancestor has an explicit value set for an inherited property, the default value for the property is used. You can use the `zfs inherit` command to clear a property value, thus causing the value to be inherited from the parent file system.

The following example uses the `zfs set` command to turn on compression for the `tank/home/sueb` file system. Then, `zfs inherit` is used to clear the `compression` property, thus causing the property to inherit the default value of `off`. Because neither `home` nor `tank` has the `compression` property set locally, the default value is used. If both had compression enabled, the value set in the most immediate ancestor would be used (`home` in this example).

```
$ zfs set compression=on tank/home/sueb
$ zfs get -r compression tank/home
NAME                  PROPERTY     VALUE     SOURCE
tank/home             compression  off       default
tank/home/glori       compression  off       default
tank/home/glori@today compression  -         -
tank/home/sueb        compression  on        local
$ zfs inherit compression tank/home/sueb
$ zfs get -r compression tank/home
NAME                  PROPERTY     VALUE     SOURCE
tank/home             compression  off       default
tank/home/glori       compression  off       default
tank/home/glori@today compression  -         -
tank/home/sueb        compression  off       default
```

The `inherit` subcommand is applied recursively when the `-r` option is specified. In the following example, the command causes the value for the `compression` property to be inherited by `tank/home` and any descendents it might have:

```
$ zfs inherit -r compression tank/home
```

> **Note:**
>
> Be aware that the use of the `-r` option clears the current property setting for all descendent file systems.

For more information about the `zfs inherit` command, see the see `zfs`(8) man page.

# Querying ZFS Properties

The simplest way to query property values is by using the `zfs list` command. For more information, see Listing Basic ZFS Information. However, for complicated queries and for scripting, use the `zfs get` command to provide more detailed information in a customized format.

You can use the `zfs get` command to retrieve any dataset property. The following example shows how to retrieve a single property value on a dataset:

```
$ zfs get checksum tank/ws
NAME            PROPERTY       VALUE                     SOURCE
tank/ws         checksum       on                        default
```

The fourth column, `SOURCE`, indicates the origin of this property value. The possible values for `SOURCE` are:

**`default`**
This property value was never explicitly set for this dataset or any of its ancestors. The default value for this property is being used.

**`inherited from` *dataset-name***
This property value is inherited from the parent dataset specified in *dataset-name*.

**`local`**
This property value was explicitly set for this dataset by using `zfs set`.

**`temporary`**
This property value was set by using the `zfs mount -o` command and is only valid for the duration of the mount. For more information about temporary mount point properties, see Using Temporary Mount Properties.

**- (none)**
This property is read-only. Its value is generated by ZFS.

You can use the special keyword `all` to retrieve all dataset property values. The following examples use the `all` keyword:

```
$ zfs get all tank/home
NAME       PROPERTY              VALUE                  SOURCE
tank/home  aclinherit            restricted             default
tank/home  aclmode               discard                default
tank/home  atime                 on                     default
tank/home  available             274G                   -
tank/home  canmount              on                     default
tank/home  casesensitivity       mixed                  -
tank/home  checksum              on                     default
tank/home  compression           off                    default
tank/home  compressratio         1.00x                  -
tank/home  copies                1                      default
```

```
tank/home  creation              Tue Jul 30 10:08 2013  -
tank/home  dedup                 off                    default
tank/home  defaultgroupquota     none                   -
tank/home  defaultuserquota      none                   -
tank/home  devices               on                     default
tank/home  encryption            off                    -
tank/home  exec                  on                     default
tank/home  keychangedate         -                      default
tank/home  keysource             none                   default
tank/home  keystatus             none                   -
tank/home  logbias               latency                default
tank/home  mlslabel              none                   -
tank/home  mounted               yes                    -
tank/home  mountpoint            /tank/home             default
tank/home  multilevel            off                    -
tank/home  nbmand                off                    default
tank/home  normalization         none                   -
tank/home  primarycache          all                    default
tank/home  quota                 none                   default
tank/home  readonly              off                    default
tank/home  recordsize            128K                   default
tank/home  referenced            31K                    -
tank/home  refquota              none                   default
tank/home  refreservation        none                   default
tank/home  rekeydate             -                      default
tank/home  reservation           none                   default
tank/home  rstchown              on                     default
tank/home  secondarycache        all                    default
tank/home  setuid                on                     default
tank/home  shadow                none                   -
tank/home  share.*               ...                    default
tank/home  snapdir               hidden                 default
tank/home  sync                  standard               default
tank/home  type                  filesystem             -
tank/home  used                  31K                    -
tank/home  usedbychildren        0                      -
tank/home  usedbydataset         31K                    -
tank/home  usedbyrefreservation  0                      -
tank/home  usedbysnapshots       0                      -
tank/home  utf8only              off                    -
tank/home  version               6                      -
tank/home  vscan                 off                    default
tank/home  xattr                 on                     default
tank/home  zoned                 off                    default
```

The `-s` option to `zfs get` enables you to specify, by source type, the properties to display. This option takes a comma-separated list indicating the desired source types. Only properties with the specified source type are displayed. The valid source types are `local`, `default`, `inherited`, `temporary`, and `none`. The following example shows all properties that have been locally set on `tank/ws`.

```
$ zfs get -s local all tank/ws
NAME     PROPERTY              VALUE                  SOURCE
tank/ws  compression           on                     local
```

Any of the above options can be combined with the `-r` option to recursively display the specified properties on all children of the specified file system. In the following example, all temporary properties on all file systems within `tank/home` are recursively displayed:

```
$ zfs get -r -s temporary all tank/home
NAME             PROPERTY       VALUE                    SOURCE
tank/home          atime          off                    temporary
```

```
tank/home/sueb     atime          off                    temporary
tank/home/mork     quota          20G                    temporary
```

You can query property values by using the `zfs get` command without specifying a target file system, which means the command operates on all pools or file systems. For example:

```
$ zfs get -s local all
tank/home               atime          off                    local
tank/home/sueb          atime          off                    local
tank/home/mork          quota          20G                    local
```

For more information about the `zfs get` command, see the `zfs`(8) man page.

## Querying ZFS Properties for Scripting

The `zfs get` command supports the `-H` and `-o` options, which are designed for scripting. You can use the `-H` option to omit header information and to replace white space with the Tab character. Uniform white space allows for easily parsable data. You can use the `-o` option to customize the output in the following ways:

- The literal `name` can be used with a comma-separated list of properties as defined in the Introducing ZFS Properties section.
- A comma-separated list of literal fields, `name`, `value`, `property`, and `source`, to be output followed by a space and an argument, which is a comma-separated list of properties.

The following example shows how to retrieve a single value by using the `-H` and `-o` options of `zfs get`:

```
$ zfs get -H -o value compression tank/home
on
```

The `-p` option reports numeric values as their exact values. For example, 1 MB would be reported as 1000000. This option can be used as follows:

```
$ zfs get -H -o value -p used tank/home
182983742
```

You can use the `-r` option, along with any of the preceding options, to recursively retrieve the requested values for all descendents. The following example uses the `-H`, `-o`, and `-r` options to retrieve the file system name and the value of the `used` property for `export/home` and its descendents, while omitting the header output:

```
$ zfs get -H -o name,value -r used export/home
```

# Mounting ZFS File Systems

This section describes how ZFS mounts file systems.

## Managing ZFS Mount Points

By default, a ZFS file system is automatically mounted when it is created. You can determine specific mount-point behavior for a file system as described in this section.

You can also set the default mount point for a pool's file system at creation time by using the `zpool create -m` command. For more information about creating pools, see Creating ZFS Storage Pools.

All ZFS file systems are mounted by ZFS at boot time by using the Service Management Facility's (SMF) `svc://system/filesystem/local` service. File systems are mounted under `/` *path*, where *path* is the name of the file system.

You can override the default mount point by using the `zfs set` command to set the `mountpoint` property to a specific path. ZFS automatically creates the specified mount point, if needed, and automatically mounts the associated file system.

ZFS file systems are automatically mounted at boot time without requiring you to edit the `/etc/vfstab` file.

The `mountpoint` property is inherited. For example, if `pool/home` has the `mountpoint` property set to `/export/stuff`, then `pool/home/user` inherits `/export/stuff/user` for its `mountpoint` property value.

To prevent a file system from being mounted, set the `mountpoint` property to `none`. In addition, the `canmount` property can be used to control whether a file system can be mounted. For more information about the `canmount` property, see The canmount Property.

File systems can also be explicitly managed through legacy mount interfaces by using `zfs set` to set the `mountpoint` property to `legacy`. Doing so prevents ZFS from automatically mounting and managing a file system. Legacy tools including the `mount` and `umount` commands, and the `/etc/vfstab` file must be used instead. For more information about legacy mounts, see Legacy Mount Points.

## Automatic Mount Points

- When you change the `mountpoint` property from `legacy` or `none` to a specific path, ZFS automatically mounts the file system.
- If ZFS is managing a file system but it is currently unmounted, and the `mountpoint` property is changed, the file system remains unmounted.

Any file system whose `mountpoint` property is not `legacy` is managed by ZFS. In the following example, a file system is created whose mount point is automatically managed by ZFS:

```
$ zfs create pool/filesystem
$ zfs get mountpoint pool/filesystem
NAME              PROPERTY      VALUE                     SOURCE
pool/filesystem   mountpoint    /pool/filesystem          default
$ zfs get mounted pool/filesystem
NAME              PROPERTY      VALUE                     SOURCE
pool/filesystem   mounted       yes                       -
```

You can also explicitly set the `mountpoint` property as shown in the following example:

```
$ zfs set mountpoint=/mnt pool/filesystem
$ zfs get mountpoint pool/filesystem
NAME              PROPERTY      VALUE                     SOURCE
pool/filesystem   mountpoint    /mnt                      local
$ zfs get mounted pool/filesystem
NAME              PROPERTY      VALUE                     SOURCE
pool/filesystem   mounted       yes                       -
```

When the `mountpoint` property is changed, the file system is automatically unmounted from the old mount point and remounted to the new mount point. Mount-point directories are created as needed. If ZFS is unable to unmount a file system due to it being active, an error is reported, and a forced manual unmount is necessary.

## Legacy Mount Points

You can manage ZFS file systems with legacy tools by setting the `mountpoint` property to `legacy`. Legacy file systems must be managed through the `mount` and `umount` commands and the `/etc/vfstab` file. ZFS does not automatically mount legacy file systems at boot time, and the ZFS `mount` and `umount` commands do not operate on file systems of this type. The following examples show how to set up and manage a ZFS file system in legacy mode:

```
$ zfs set mountpoint=legacy tank/home/glori
$ mount -F zfs tank/home/eschrock /mnt
```

To automatically mount a legacy file system at boot time, you must add an entry to the `/etc/vfstab` file. The following example shows what the entry in the `/etc/vfstab` file might look like:

```
#device         device        mount           FS      fsck    mount   mount
#to mount       to fsck       point           type    pass    at boot options
#

tank/home/glori -        /mnt           zfs        -        yes        -
```

The `device to fsck` and `fsck pass` entries are set to `-` because the `fsck` command is not applicable to ZFS file systems.

# Mounting ZFS File Systems

ZFS automatically mounts file systems when file systems are created or when the system boots. Use of the `zfs mount` command is necessary only when you need to change mount options, or explicitly mount or unmount file systems.

The `zfs mount` command with no arguments shows all currently mounted file systems that are managed by ZFS. Legacy managed mount points are not displayed. For example:

```
$ zfs mount | grep tank/home
zfs mount | grep tank/home
tank/home                       /tank/home
tank/home/sueb                  /tank/home/sueb
```

You can use the `-a` option to mount all ZFS managed file systems. Legacy managed file systems are not mounted. For example:

```
$ zfs mount -a
```

By default, ZFS does not allow mounting on top of a nonempty directory. For example:

```
$ zfs mount tank/home/glori
cannot mount 'tank/home/glori': filesystem already mounted
```

Legacy mount points must be managed through legacy tools. An attempt to use ZFS tools results in an error. For example:

```
$ zfs mount tank/home/bhall
cannot mount 'tank/home/bhall': legacy mountpoint
use mount(8) to mount this filesystem
$ mount -F zfs tank/home/bhallm
```

When a file system is mounted, it uses a set of mount options based on the property values associated with the file system. The correlation between ZFS properties and mount options is as follows:

**atime**
atime/noatime

**devices**
devices/nodevices

**exec**
exec/noexec

**nbmand**
nbmand/nonbmand

**readonly**
ro/rw

**setuid**
setuid/nosetuid

**xattr**
xattr/noaxttr

The mount option `nosuid` is an alias for `nodevices,nosetuid`.

You can use the NFSv4 mirror mount features to help you better manage NFS-mounted ZFS home directories.

When file systems are created on the NFS server, the NFS client can automatically discover these newly created file systems within their existing mount of a parent file system.

For example, if the server `neo` already shares the `tank` file system and client `zee` has it mounted, `/tank/baz` is automatically visible on the client after it is created on the server.

```
zee$ mount neo:/tank /mnt
zee$ ls /mnt
baa    bar

neo$ zfs create tank/baz

zee% ls /mnt
baa    bar    baz
zee% ls /mnt/baz
file1    file2
```

## Using Temporary Mount Properties

If any of the mount options described in the preceding section are set explicitly by using the `-o` option with the `zfs mount` command, the associated property value is temporarily overridden. These property values are reported as `temporary` by the `zfs get` command and revert back to their original values when the file system is unmounted. If a property value is changed while the file system is mounted, the change takes effect immediately, overriding any temporary setting.

In the following example, the read-only mount option is temporarily set on the `tank/home/nneke` file system. The file system is assumed to be unmounted.

```
$ zfs mount -o ro users/home/nneke
```

To temporarily change a property value on a file system that is currently mounted, you must use the special `remount` option. In the following example, the `atime` property is temporarily changed to `off` for a file system that is currently mounted:

```
$ zfs mount -o remount,noatime users/home/nneke
NAME             PROPERTY  VALUE  SOURCE
users/home/nneke  atime     off    temporary
$ zfs get atime users/home/perrin
```

For more information about the `zfs mount` command, see the `zfs`(8) man page.

## Unmounting ZFS File Systems

You can unmount ZFS file systems by using the `zfs unmount` subcommand. The `unmount` command can take either the mount point or the file system name as an argument.

In the following example, a file system is unmounted by its file system name:

```
$ zfs unmount users/home/mork
```

In the following example, the file system is unmounted by its mount point:

```
$ zfs unmount /users/home/mork
```

The `unmount` command fails if the file system is busy. To forcibly unmount a file system, you can use the `-f` option. Be cautious when forcibly unmounting a file system if its contents are actively being used. Unpredictable application behavior can result.

```
$ zfs unmount tank/home/glori
cannot unmount '/tank/home/glori': Device busy
$ zfs unmount -f tank/home/glori
```

To provide for backward compatibility, the legacy `umount` command can be used to unmount ZFS file systems. For example:

```
$ umount /tank/home/glori
```

For more information about the `zfs umount` command, see the `zfs`(8) man page.

# Sharing and Unsharing ZFS File Systems

The Oracle Solaris 11.1 release simplifies ZFS share administration by leveraging ZFS property inheritance. The new share syntax is enabled on pools running pool version 34.

The following are the file system packages for NFS and SMB:

- NFS client and server packages
  - `service/file-system/nfs` (server)
  - `service/file-system/nfs` (client)

  For additional NFS configuration information, see *Managing Network File Systems in Oracle Solaris 11.4* .
- SMB client and server packages
  - `service/file-system/smb` (server)

  - `service/file-system/smb` (client)

    For additional SMB configuration information including SMB password management, see Managing SMB Mounts in Your Local Environment in *Managing SMB File Sharing and Windows Interoperability in Oracle Solaris 11.4* .

Multiple shares can be defined per file system. A share name uniquely identifies each share. You can define the properties that are used to share a particular path in a file system. By default, all file systems are unshared. In general, the NFS server services are not started until a share is created. If you create a valid share, the NFS services are started automatically. If a ZFS file system's `mountpoint` property is set to legacy, the file system can only be shared by using the legacy `share` command.

- The `share.nfs` property replaces the `sharenfs` property in previous releases to define and publish an NFS share.
- The `share.smb` property replaces the `sharesmb` property in previous releases to define and publish an SMB share.
- Both the `sharenfs` property and `sharesmb` property are aliases to the `share.nfs` property and the `sharenfs` property.
- The `/etc/dfs/dfstab` file is no longer used to share file systems at boot time. Setting these properties share file systems automatically. SMF manages ZFS or UFS share information so that file systems are shared automatically when the system is rebooted. This feature means that all file systems whose `sharenfs` or `sharesmb` property are not set to off are shared at boot time.
- The `sharemgr` interface is no longer available. The legacy `share` command is still available to create a legacy share. See the examples below.
- The `share -a` command is like the previous `share -ap` command so that sharing a file system is persistent. The `share -p` command is no longer available.

For example, if you want to share the `tank/home` file system, use syntax similar to the following:

```
$ zfs set share.nfs=on tank/home
```

In preceding example, where the `share.nfs` property is set on the `tank/home` file system, the `share.nfs` property value is inherited to any descendent file systems. For example:

```
$ zfs create tank/home/userA
$ zfs create tank/home/userB
```

You can also specify additional property values or modify existing property values on existing file system shares. For example:

```
$ zfs set share.nfs.nosuid=on tank/home/userA
$ zfs set share.nfs=on tank/home/userA
```

# About Sharing Labeled File Systems

To protect their sensitive contents, your company can label files and file systems With labeled file systems, stricter security requirements such as encryption and access controls are enforced.

Oracle Solaris 11.4, by default, prohibits sharing of labeled NFS files. You can grant sharing permissions to these files through the `share.nfs.labeled` property. See examples in Changing ZFS Share Property Values.

For more information about labeled file systems, see the following resources:

- Chapter 3, Labeling Files for Data Loss Protection in *Securing Files and Verifying File Integrity in Oracle Solaris 11.4*
- Sharing a Labeled File System in *Managing Network File Systems in Oracle Solaris 11.4*

## Legacy ZFS Sharing Syntax

Oracle Solaris 11 syntax is still supported so that you can share file systems in two steps. This syntax is supported in all pool versions.

- First, use the `zfs set share` command to create an NFS or SMB share of ZFS file system.

```
$ zfs create rpool/fs1
$ zfs set share=name=fs1,path=/rpool/fs1,prot=nfs rpool/fs1
name=fs1,path=/rpool/fs1,prot=nfs
```

- Then, set the `sharenfs` or `sharesmb` property to on to publish the share. For example:

```
$ zfs set sharenfs=on rpool/fs1
$ grep fs1 /etc/dfs/sharetab
/rpool/fs1      fs1     nfs     sec=sys,rw
```

File system shares can be displayed with the legacy `zfs get share` command.

```
$ zfs get share rpool/fs1
NAME       PROPERTY  VALUE  SOURCE
rpool/fs1  share     name=fs1,path=/rpool/fs1,prot=nfs  local
```

In addition, the `share` command to share a file system, similar to the syntax in the Oracle Solaris 10 release, is still supported to share any directory within a file system. For example, to share a ZFS file system:

```
$ share -F nfs /tank/zfsfs
$ grep zfsfs /etc/dfs/sharetab
/tank/zfsfs    tank_zfsfs     nfs     sec=sys,rw
```

The above syntax is identical to sharing a UFS file system:

```
$ share -F nfs /ufsfs
$ grep ufsfs /etc/dfs/sharetab
/ufsfs          -               nfs     rw
/tank/zfsfs     tank_zfsfs      nfs     rw
```

## New ZFS Sharing Syntax

The `zfs set` command is used to share and publish a ZFS file system over the NFS or SMB protocols. Or, you can set the `share.nfs` or `share.smb` property when the file system is created.

For example, the `tank/sales` file system is created and shared. The default share permissions are read-write for everyone. The descendent `tank/sales/logs` file system is also shared automatically because the `share.nfs` property is inherited to descendent file systems and the `tank/sales/log` file system is set to read-only access.

```
$ zfs create -o share.nfs=on tank/sales
$ zfs create -o share.nfs.ro=\* tank/sales/logs
$ zfs get -r share.nfs tank/sales
NAME             PROPERTY   VALUE  SOURCE
tank/sales       share.nfs  on     local
tank/sales%      share.nfs  on     inherited from tank/sales
```

```
tank/sales/log   share.nfs  on     inherited from tank/sales
tank/sales/log%  share.nfs  on     inherited from tank/sales
```

You can provide root access to a specific system for a shared file system as follows:

```
$ zfs set share.nfs=on tank/home/data
$ zfs set share.nfs.sec.default.root=neo.daleks.com tank/home/data
```

## ZFS Sharing with Per-Property Inheritance

In pools that have been upgraded to the latest pool version 34, new sharing syntax is available that makes use of ZFS property inheritance to ease share maintenance. Each sharing characteristic becomes a separate `share` property. The `share` properties are identified by names that start with the `share.` prefix. Examples of `share` properties include `share.desc`, `share.nfs.nosuid`, and `share.smb.guestok`.

The `share.nfs` property controls whether NFS sharing is enabled. The `share.smb` property controls whether SMB sharing is enabled. The legacy `sharenfs` and `sharesmb` property names can still be used, because in new pools, `sharenfs` is an alias for `share.nfs` and `sharesmb` is an alias for `share.smb`. If you want to share the `tank/home` file system, use syntax similar to the following:

```
$ zfs set share.nfs=on tank/home
```

In this example, the `share.nfs` property value is inherited to any descendent file systems. For example:

```
$ zfs create tank/home/userA
$ zfs create tank/home/userB
$ grep tank/home /etc/dfs/sharetab
/tank/home      tank_home       nfs     sec=sys,rw
/tank/home/userA        tank_home_userA nfs     sec=sys,rw
/tank/home/userB        tank_home_userB nfs     sec=sys,rw
```

## ZFS Sharing Inheritance in Older Pools

In older pools, only the `sharenfs` and `sharesmb` properties are inherited by descendent file systems. Other sharing characteristics are stored in the `.zfs/shares` file for each share and are not inherited.

A special rule is that whenever a new file system is created that inherits `sharenfs` or `sharesmb` from its parent, a default share is created for that file system from the `sharenfs` or `sharesmb` value. Note that when `sharenfs` is simply on, the default share that is created in a descendent file system has only the default NFS characteristics. For example:

```
$ zpool get version tank
NAME  PROPERTY  VALUE  SOURCE
tank  version   33     default
$ zfs create -o sharenfs=on tank/home
$ zfs create tank/home/userA
$ grep tank/home /etc/dfs/sharetab
/tank/home      tank_home       nfs     sec=sys,rw
/tank/home/userA        tank_home_userA nfs     sec=sys,r
```

## ZFS Named Shares

You can also create a *named* share, which provides more flexibility in setting permissions and properties in an SMB environment. For example:

```
$ zfs share -o share.smb=on tank/workspace%myshare
```

In the preceding example, the `zfs share` command creates an SMB share called `myshare` of the `tank/workspace` file system. You can access the SMB share and display or set specific permissions or ACLs through the `.zfs/shares` directory of the file system. Each SMB share is represented by a separate `.zfs/shares` file. For example:

```
$ ls -lv /tank/workspace/.zfs/shares
-rwxrwxrwx+  1 root     root           0 May 15 10:31 myshare
0:everyone@:read_data/write_data/append_data/read_xattr/write_xattr
/execute/delete_child/read_attributes/write_attributes/delete
/read_acl/write_acl/write_owner/synchronize:allow
```

Named shares inherit sharing properties from the parent file system. If you add the `share.smb.guestok` property to the parent file system in the previous example, this property is inherited to the named share. For example:

```
$ zfs get -r share.smb.guestok tank/workspace
NAME                   PROPERTY           VALUE  SOURCE
tank/workspace         share.smb.guestok  on     inherited from tank
tank/workspace%myshare share.smb.guestok  on     inherited from tank
```

Named shares can be helpful in the NFS environment when defining shares for a subdirectory of the file system. For example:

```
$ zfs create -o share.nfs=on -o share.nfs.anon=99 -o share.auto=off tank/home
$ mkdir /tank/home/userA
$ mkdir /tank/home/userB
$ zfs share -o share.path=/tank/home/userA tank/home%userA
$ zfs share -o share.path=/tank/home/userB tank/home%userB
$ grep tank/home /etc/dfs/sharetab
/tank/home/userA        userA   nfs     anon=99,sec=sys,rw
/tank/home/userB        userB   nfs     anon=99,sec=sys,rw
```

The above example also illustrates that setting the `share.auto` to off for a file system turns off the auto share for that file system while leaving all other property inheritance intact. Unlike most other sharing properties, the `share.auto` property is not inheritable.

Named shares are also used when creating a public NFS share. A public share can only be created on a named NFS share. For example:

```
$ zfs create -o mountpoint=/pub tank/public
$ zfs share -o share.nfs=on -o share.nfs.public=on tank/public%pubshare
$ grep pub /etc/dfs/sharetab
/pub    pubshare        nfs     public,sec=sys,rw
```

See the share_nfs(8) and share_smb(8) man pages for a detailed description of NFS and SMB share properties.

## ZFS Automatic Shares

When an automatic (auto) share is created, a unique resource name is constructed from the file system name. The constructed name is a copy of the file system name except that the characters in the file system name that would be illegal in the resource name, are replaced with underscore (_) characters. For example, the resource name of `data/home/john` is `data_home_john`.

Setting a `share.autoname` property name allows you to replace the file system name with a specific name when creating the auto share. The specific name is also used to replace the prefix file system name in the case of inheritance. For example:

```
$ zfs create -o share.smb=on -o share.autoname=john data/home/john
$ zfs create data/home/john/backups
$ grep john /etc/dfs/sharetab
/data/home/john john    smb
/data/home/john/backups john_backups    smb
```

If a legacy `share` command or the `zfs set share` command is used on a file system that has not yet been shared, its `share.auto` value is automatically set to `off`. The legacy commands always create named shares. This special rule prevents the auto share from interfering with the named share that is being created.

## Displaying ZFS Share Information

Display the value of the file sharing properties by using `zfs get` command. The following example shows how to display the `share.nfs` property for a single file system:

```
$ zfs get share.nfs tank/sales
NAME        PROPERTY   VALUE  SOURCE
tank/sales  share.nfs  on     local
```

The following example shows how to display the `share.nfs` property for descendent file systems:

```
$ zfs get -r share.nfs tank/sales
NAME             PROPERTY   VALUE  SOURCE
tank/sales       share.nfs  on     local
tank/sales%      share.nfs  on     inherited from tank/sales
tank/sales/log   share.nfs  on     inherited from tank/sales
tank/sales/log%  share.nfs  on     inherited from tank/sales
```

The extended share property information is not available in the `zfs get all` command syntax.

You can display specific details about NFS or SMB share information by using the following syntax:

```
$ zfs get share.nfs.all tank/sales
NAME        PROPERTY             VALUE  SOURCE
tank/sales  share.nfs.aclok      off    default
tank/sales  share.nfs.anon              default
tank/sales  share.nfs.charset.*  ...    default
tank/sales  share.nfs.cksum             default
tank/sales  share.nfs.index             default
tank/sales  share.nfs.log               default
tank/sales  share.nfs.noaclfab   off    default
tank/sales  share.nfs.nosub      off    default
tank/sales  share.nfs.nosuid     off    default
tank/sales  share.nfs.public     -      -
tank/sales  share.nfs.sec               default
tank/sales  share.nfs.sec.*      ...    default
```

Because there are many share properties, consider displaying the properties with a non-default value. For example:

```
$ zfs get -e -s local,received,inherited share.all tank/home
NAME       PROPERTY           VALUE  SOURCE
tank/home  share.auto         off    local
tank/home  share.nfs          on     local
tank/home  share.nfs.anon     99     local
tank/home  share.protocols    nfs    local
tank/home  share.smb.guestok  on     inherited from tank
```

## Changing ZFS Share Property Values

You can change share property values by specifying new or modified properties on a file system share. For example, if the read-only property is set when the file system is created, the property can be set to off.

```
$ zfs create -o share.nfs.ro=\* tank/data
$ zfs get share.nfs.ro tank/data
NAME       PROPERTY              VALUE  SOURCE
tank/data  share.nfs.sec.sys.ro  *      local
$ zfs set share.nfs.ro=none tank/data
$ zfs get share.nfs.ro tank/data
NAME       PROPERTY              VALUE  SOURCE
tank/data  share.nfs.sec.sys.ro  off    local
```

If you create an SMB share, you can also add the NFS share protocol. For example:

```
$ zfs set share.smb=on tank/multifs
$ zfs set share.nfs=on tank/multifs
$ grep multifs /etc/dfs/sharetab
/tank/multifs   tank_multifs    nfs     sec=sys,rw
/tank/multifs   tank_multifs    smb     -
```

Remove the SMB protocol:

```
$ zfs set share.smb=off tank/multifs
$ grep multifs /etc/dfs/sharetab
/tank/multifs   tank_multifs    nfs     sec=sys,rw
```

You can rename a named share. For example:

```
$ zfs share -o share.smb=on tank/home/abc%abcshare
$ grep abc /etc/dfs/sharetab
/tank/home/abc  abcshare        smb     -
$ zfs rename tank/home/abc%abcshare tank/home/abc%a1share
$ grep abc /etc/dfs/sharetab
/tank/home/abc  a1share         smb     -
```

You can grant sharing access to labeled file systems. In the following example, `rpool/export/home` is a labeled file system which is configured to be shared.

```
$ zfs create -o multilevel=on -o encryption=on rpool/ftp-files
$ zfs set =/ftpsource rpool/ftp-files
$ setlabel "Conf - Internal Use Only" /ftpsource

$ zfs set share.nfs.labeled=on rpool/ftp-files
$ zfs set share.nfs=on rpool/ftp-files
```

You can also enable sharing of labeled file systems with the `zfs share` command.

```
$ zfs share -o nfs=on -o share.nfs.labeled=on rpool/ftp-files
```

## Publishing and Unpublishing ZFS Shares

You can temporarily unshare a named share without destroying it by using the `zfs unshare` command. For example:

```
$ zfs unshare tank/home/abc%a1share
$ grep abc /etc/dfs/sharetab
#
```

```
$ zfs share tank/home/abc%a1share
$ grep abc /etc/dfs/sharetab
/tank/home/abc  a1share smb     -
```

When the `zfs unshare` command is issued, all file system shares are unshared. These shares remain unshared until the `zfs share` command is issued for the file system or the `share.nfs` or `share.smb` property is set for the file system.

Defined shares are not removed when the `zfs unshare` command is issued, and they are re-shared the next time the `zfs share` command is issued for the file system or the `share.nfs` or `share.smb` property is set for the file system.

## Removing a ZFS Share

You can unshare a file system share by setting the `share.nfs` or `share.smb` property to off. For example:

```
$ zfs set share.nfs=off tank/multifs
$ grep multifs /etc/dfs/sharetab
$
```

You can permanently remove a named share by using the `zfs destroy` command. For example:

```
$ zfs destroy tank/home/abc%a1share
```

## ZFS File Sharing Within a Non-Global Zone

Starting with Oracle Solaris 11, you can create and publish NFS shares in a non-global zone.

- If a ZFS file system is mounted and available in a non-global zone, it can be shared in that zone.
- A file system can be shared in the global zone if it is not delegated to a non-global zone and is not mounted in a non-global zone. If a file system is added to a non-global zone, it can only be shared by using the legacy `share` command.

For example, the `/export/home/data` and `/export/home/data1` file systems are available in the `zfszone`.

```
zfszone$ share -F nfs /export/home/data
zfszone#  cat /etc/dfs/sharetab

zfszone$ zfs set share.nfs=on tank/zones/export/home/data1
zfszone$ cat /etc/dfs/sharetab
```

# ZFS Sharing Migration/Transition Issues

Review the following transition issues:

- **Importing file systems with older sharing properties** - When importing a pool or receiving a file system stream that was created before Oracle Solaris 11, the `sharenfs` and `sharesmb` properties include all the share properties directly in the property value. In most cases, these legacy share properties are converted to an equivalent set of named shares as soon as each file system is shared. Since import operations trigger mounting and sharing in most cases, the conversion to named shares happens directly during the import process.

- **Upgrading from Oracle Solaris 11** - The first file system sharing after a pool upgrade to version 34 can take a long time because the named shares are converted to the new format. The named shares created by the upgrade process are correct but cannot take advantage of share property inheritance.
  - Display share property values:

    ```
    $ zfs get share.nfs filesystem
    $ zfs get share.smb filesystem
    ```

  - If you boot back to an older BE, reset the `sharenfs` and `sharesmb` properties to their original values.
- **Upgrading from Oracle Solaris 11** – In Oracle Solaris 11 and Oracle Solaris 11.1, the `sharenfs` and `sharesmb` properties can have only `off` and `on` values. These properties are no longer used to define share characteristics.

  The `/etc/dfs/dfstab` file is no longer used to share file systems at boot time. At boot time, all mounted ZFS file systems that include enabled file system shares are automatically shared. A share is enabled when it `sharenfs` or `sharesmb` is set to `on`.

  The `sharemgr` interface is no longer available. The legacy `share` command is still available to create a legacy share. The `share -a` command is like the previous `share -ap` command so that sharing a file system is persistent. The `share -p` command is no longer available.
- **Upgrading your system** – ZFS shares are incorrect if you boot back to an Oracle Solaris 11 BE due to property changes in this release. Non-ZFS shares are unaffected. If you plan to boot back to an older BE, first save a copy of the existing share configuration prior to the `pkg update` operation to be able to restore the ZFS share configuration.

  In the older BE, use the `sharemgr show -vp` command to list all shares and their configuration.

  Use the following commands to display share property values:

  ```
  $ zfs get sharenfs filesystem
  $ zfs get sharesmb filesystem
  ```

  If you back to an older BE, reset the `sharenfs` and `sharesmb` properties and any shares defined with `sharemgr` to their original values.
- **Legacy unsharing behavior** – Using the `unshare -a` command or `unshareall` command unshares a file system, but does not update the SMF shares repository. If you try to re-share the existing share, the shares repository is checked for conflicts, and an error is displayed.

# Troubleshooting ZFS File System Sharing Problems

Review the following share error conditions:

- **New shares or previous shares are not shared**
  - **Confirm the pool and the file system versions are current** - If new shares are not shared by setting the `share.nfs` or `share.smb` property, then confirm that the pool version is 34 and the file system version is 6.
  - **Share must exist before NFS services start**- NFS server services do not run until a file system is shared. Create the NFS share first and then attempt to access the share remotely.

– **System with existing shares was upgraded but shares are not available** - A system with existing shares is upgraded but attempts to reshare the shares fail. The shares might not be shared because the `share.auto` property is disabled. If `share.auto` is set to off, only named shares are available, which enforces compatibility with earlier sharing syntax. The existing shares might look like this:

```
$ zfs get share
NAME                        PROPERTY  VALUE  SOURCE
tank/data                   share     name=data,path=/tank/data,prot=nfs  local
```

1. Ensure that the `share.auto` property is enabled. If not, enable it.

```
$ zfs get -r share.auto tank/data
$ zfs set share.auto=on tank/data
```

2. Reshare the file system.

```
$ zfs set -r share.nfs=on tank/data
```

3. You might also need to remove named shares and recreate them before the preceding command is successful.

```
$ zfs list -t share -Ho name -r tank/data | xargs -n1 zfs destroy
```

4. If necessary, recreate the named shares.

```
$ zfs create -o share.nfs=on tank/data%share
```

- **Sharing properties including named shares are not included in snapshots** - Share properties and `.zfs/shares` files are treated differently in `zfs clone` and `zfs send` operations. The `.zfs/shares` files are included in snapshots and are preserved in `zfs clone` and `zfs send` operations. For a description of the behavior of properties during `zfs send` and `zfs receive` operations, see Applying Different Property Values to a ZFS Snapshot Stream. After a clone operation, all files are from the pre-clone snapshot, whereas the properties are inherited from the clone's new position in the ZFS file system hierarchy.
- **Named share request fails** - If a request to create a named share fails because the share would conflict with the auto share, you may have to disable the `auto.share` property.
- **Pool with shares was previously exported** - When a pool is imported read-only, neither its properties nor its files can be modified so creating a new share fails. If the shares existed before the pool was exported, the existing sharing characteristics are used, if possible.

The following table identifies know share states and how to resolve them.

| Share State | Description | Resolution |
|---|---|---|
| `INVALID` | The share is invalid because it is internally inconsistent or because it conflicts with another share. | Attempt to re-share the invalid share by using the following command:<br>`$ zfs share FS%share`<br>Using this command displays an error message about which aspect of the share is failing validation. Correct this, then retry the share. |
| `SHARED` | The share is shared. | None needed. |
| `UNSHARED` | The share is valid but is unshared. | Use the `zfs share` command to re-share either the individual share or the parent file system. |

| Share State | Description | Resolution |
|---|---|---|
| UNVALIDATED | The share is not yet validated. The file system that contains the share might not be in a shareable state. For example, it is not mounted or it is delegated to a zone other than the current zone. Alternatively, the ZFS properties representing the desired share have been created, but have not yet been validated as a legal share. | Use the `zfs share` command to re-share the individual share or the parent file system. If the file system itself is shareable, an attempt to re-share will either succeed in sharing (and transition the state to shared) or fail to share (and transition the state to invalid). Or, you can use the `share -A` command to list all shares in all mounted file systems. This will cause all shares in mounted file systems to be resolved as either unshared (valid but not yet shared) or invalid. |

# Specifying Unicode Versions

Add the following note to Unicode Overview in *International Language Environments Guide for Oracle Solaris 11.4* :

> **Note:**
>
> Oracle Solaris 11.4 SRU 51 introduces Unicode Version 14.0.0 for ZFS file system namespaces in ZFS file system Version 8 and ZFS pool Version 49. For more information, see Specifying Unicode Versions in *Managing ZFS File Systems in Oracle Solaris* .

# Setting ZFS Quotas

You can use the `quota` property to set a limit on the amount of disk space a file system can use. In addition, you can use the `reservation` property to guarantee that a specified amount of disk space is available to a file system. Both properties apply to the file system on which they are set and all descendents of that file system.

That is, if a quota is set on the `tank/home` file system, the total amount of disk space used by `tank/home` *and all of its descendents* cannot exceed the quota. Similarly, if `tank/home` is given a reservation, `tank/home` *and all of its descendents* draw from that reservation. The amount of disk space used by a file system and all of its descendents is reported by the `used` property.

The `refquota` and `refreservation` properties are used to manage file system space without accounting for disk space consumed by descendents, such as snapshots and clones.

In this Oracle Solaris release, you can set a *user* or a *group* quota on the amount of disk space consumed by files that are owned by a particular user or group. The user and group quota properties cannot be set on a volume, on a file system before file system version 4, or on a pool before pool version 15.

Consider the following points to determine which quota and reservation features might best help you manage your file systems:

- The `quota` and `reservation` properties are convenient for managing disk space consumed by file systems and their descendents.

- The `refquota` and `refreservation` properties are appropriate for managing disk space consumed by file systems.
- Setting the `refquota` or `refreservation` property higher than the `quota` or `reservation` property has no effect. If you set the `quota` or `refquota` property, operations that try to exceed either value fail. It is possible to a exceed a `quota` that is greater than the `refquota`. For example, if some snapshot blocks are modified, you might actually exceed the `quota` before you exceed the `refquota`.
- User and group quotas provide a way to more easily manage disk space with many user accounts, such as in a university environment.
- A convenient way to set a quota on a large file system for many different users is to set a default user or group quota.

For more information about setting quotas and reservations, see Setting Quotas on ZFS File Systems and Setting Reservations on ZFS File Systems.

# Setting Quotas on ZFS File Systems

Quotas on ZFS file systems can be set and displayed by using the `zfs set` and `zfs get` commands. In the following example, a quota of 10GB is set on `tank/home/sueb`:

```
$ zfs set quota=10G tank/home/sueb
$ zfs get quota tank/home/sueb
NAME            PROPERTY  VALUE  SOURCE
tank/home/sueb  quota     10G    local
```

Quotas also affect the output of the `zfs list` and `df` commands. For example:

```
$ zfs list -r tank/home
NAME                USED  AVAIL  REFER  MOUNTPOINT
tank/home          1.45M  66.9G    36K  /tank/home
tank/home/glori     547K  66.9G   547K  /tank/home/glori
tank/home/sueb      322K  10.0G   291K  /tank/home/sueb
tank/home/sueb/ws    31K  10.0G    31K  /tank/home/sueb/ws
tank/home/mork       31K  66.9G    31K  /tank/home/mork
$ df -h /tank/home/sueb
Filesystem            Size  Used Avail Use% Mounted on
tank/home/sueb         10G  306K   10G   1% /tank/home/sueb
```

Note that although `tank/home` has 66.9GB of disk space available, `tank/home/sueb` and `tank/home/sueb/ws` each have only 10GB of disk space available, due to the quota on `tank/home/sueb`.

You can set a `refquota` on a file system that limits the amount of disk space that the file system can consume. This limit does not include disk space that is consumed by descendents. For example, studentA's 10GB quota is not impacted by space that is consumed by snapshots.

```
$ zfs set refquota=10g students/studentA
$ zfs list -t all -r students
NAME                         USED  AVAIL  REFER  MOUNTPOINT
students                     150M  66.8G    32K  /students
students/studentA            150M  9.85G   150M  /students/studentA
students/studentA@yesterday     0      -   150M  -
$ zfs snapshot students/studentA@today
$ zfs list -t all -r students
students                     150M  66.8G    32K  /students
students/studentA            150M  9.90G   100M  /students/studentA
students/studentA@yesterday  50.0M      -   150M  -
students/studentA@today          0      -   100M  -
```

For additional convenience, you can set another quota on a file system to help manage the disk space that is consumed by snapshots. For example:

```
$ zfs set quota=20g students/studentA
$ zfs list -t all -r students
NAME                          USED  AVAIL  REFER  MOUNTPOINT
students                      150M  66.8G    32K  /students
students/studentA             150M  9.90G   100M  /students/studentA
students/studentA@yesterday  50.0M      -   150M  -
students/studentA@today          0      -   100M  -
```

In this scenario, `studentA` might reach the `refquota` (10GB) hard limit, but `studentA` can remove files to recover, even if snapshots exist.

In the preceding example, the smaller of the two quotas (10GB as compared to 20GB) is displayed in the `zfs list` output. To view the value of both quotas, use the `zfs get` command. For example:

```
$ zfs get refquota,quota students/studentA
NAME               PROPERTY  VALUE              SOURCE
students/studentA  refquota  10G                local
students/studentA  quota     20G                local
```

Enforcement of a file system quota might be delayed by several seconds. This delay means that a user might exceed the file system quota before the system notices that the file system is over quota and refuses additional writes with the `EDQUOT` error message.

# Setting User and Group Quotas on a ZFS File System

You can set a user quota or a group quota by using the `zfs userquota` or `zfs groupquota` commands, respectively. For example:

```
$ zfs create students/compsci
$ zfs set userquota@student1=10G students/compsci
$ zfs create students/labstaff
$ zfs set groupquota@labstaff=20GB students/labstaff
```

Display the current user quota or group quota as follows:

```
$ zfs get userquota@student1 students/compsci
NAME              PROPERTY            VALUE               SOURCE
students/compsci  userquota@student1  10G                 local
$ zfs get groupquota@labstaff students/labstaff
NAME               PROPERTY             VALUE                SOURCE
students/labstaff  groupquota@labstaff  20G                  local
```

You can display general user or group disk space usage by querying the following properties:

```
$ zfs userspace students/compsci
TYPE        NAME      USED  QUOTA
POSIX User  root      350M   none
POSIX User  student1  426M    10G
$ zfs groupspace students/labstaff
TYPE         NAME      USED  QUOTA
POSIX Group  labstaff  250M    20G
POSIX Group  root      350M   none
```

To identify individual user or group disk space usage, query the following properties:

```
$ zfs get userused@student1 students/compsci
NAME              PROPERTY           VALUE              SOURCE
```

```
students/compsci  userused@student1  550M              local
$ zfs get groupused@labstaff students/labstaff
NAME              PROPERTY            VALUE              SOURCE
students/labstaff  groupused@labstaff  250                local
```

The user and group quota properties are not displayed by using the `zfs get all` *dataset* command, which displays a list of all of the other file system properties.

You can remove a user quota or group quota as follows:

```
$ zfs set userquota@student1=none students/compsci
$ zfs set groupquota@labstaff=none students/labstaff
```

User and group quotas on ZFS file systems provide the following features:

- A user quota or group quota that is set on a parent file system is not automatically inherited by a descendent file system.
- However, the user or group quota is applied when a clone or a snapshot is created from a file system that has a user or group quota. Likewise, a user or group quota is included with the file system when a stream is created by using the `zfs send` command, even without the `-R` option.
- Unprivileged users can only access their own disk space usage. The root user or a user who has been granted the `userused` or `groupused` privilege, can access everyone's user or group disk space accounting information.
- The `userquota` and `groupquota` properties cannot be set on ZFS volumes, on a file system prior to file system version 4, or on a pool prior to pool version 15.

Enforcement of user and group quotas might be delayed by several seconds. This delay means that a user might exceed the user quota before the system notices that the user is over quota and refuses additional writes with the `EDQUOT` error message.

You can use the legacy `quota` command to review user quotas in an NFS environment, for example, where a ZFS file system is mounted. Without any options, the `quota` command only displays output if the user's quota is exceeded. For example:

```
$ zfs set userquota@student1=10m students/compsci
$ zfs userspace students/compsci
TYPE        NAME      USED  QUOTA
POSIX User  root      350M   none
POSIX User  student1  550M    10M
$ quota student1
Block limit reached on /students/compsci
```

If you reset the user quota and the quota limit is no longer exceeded, you can use the `quota -v` command to review the user's quota. For example:

```
$ zfs set userquota@student1=10GB students/compsci
$ zfs userspace students/compsci
TYPE        NAME      USED  QUOTA
POSIX User  root      350M   none
POSIX User  student1  550M    10G
$ quota student1
$ quota -v student1
Disk quotas for student1 (uid 102):
Filesystem     usage  quota  limit    timeleft  files  quota  limit    timeleft
/students/compsci
563287 10485760 10485760          -      -      -      -          -
```

## Setting Default User and Group Quotas

Starting in the Oracle Solaris 11.3 release, you can set a default user quota or a default group quota that is applied automatically for anyone who does not have a specific quota defined. Similar to specific user and group quotas, default user and group quotas are not inheritable to descendent file systems. In addition, if a default user or group quota is set on a top-level file system, space consumed in descendent file systems is not charged to the top-level file system's default quota.

You can set a default user quota on a large shared file system. For example:

```
$ zfs set defaultuserquota=30gb students/labstaff/admindata
```

Using a default user quota on a large shared file system allows you to restrict growth without specifying individual user quotas. You can also monitor who is using the top-level file system.

```
$ zfs userspace students/labstaff/admindata
TYPE        NAME     USED  QUOTA  SOURCE
POSIX User  admin1  2.00G    30G  default
POSIX User  admin2  4.00G    30G  default
POSIX User  root       3K    30G  default
```

In the above example, each user that does not have an existing quota is allowed 30GB of disk space in `students/labstaff/admindata`. Contrasting this behavior to setting a 30GB file system quota on `students/labstaff/admindata`, means that a cumulative quota of 30GB would apply to all users who didn't have an existing quota.

You can set a default group quota in a similar way. For example, the following syntax sets a 120GB quota on the `students/math` file system. You can use the `zfs groupspace` command to track usage of a top-level file system with a default group quota.

```
$ zfs set defaultgroupquota=120g students/math
$ zfs groupspace students/math
TYPE         NAME       USED  QUOTA  SOURCE
POSIX Group  root         6K   120G  default
POSIX Group  students  40.0G   120G  default
```

# Setting Reservations on ZFS File Systems

A ZFS *reservation* is an allocation of disk space from the pool that is guaranteed to be available to a dataset. As such, you cannot reserve disk space for a dataset if that space is not currently available in the pool. The total amount of all outstanding, unconsumed reservations cannot exceed the amount of unused disk space in the pool. ZFS reservations can be set and displayed by using the `zfs set` and `zfs get` commands. For example:

```
$ zfs set reservation=5G tank/home/bhall
$ zfs get reservation tank/home/bhall
NAME            PROPERTY     VALUE   SOURCE
tank/home/bhall  reservation  5G      local
```

Reservations can affect the output of the `zfs list` command. For example:

```
$ zfs list -r tank/home
NAME                USED  AVAIL  REFER  MOUNTPOINT
tank/home          5.00G  61.9G    37K  /tank/home
tank/home/bhall       31K  66.9G    31K  /tank/home/bhall
tank/home/sueb      337K  10.0G   306K  /tank/home/sueb
```

```
tank/home/glori     547K  61.9G   547K  /tank/home/glori
tank/home/mork       31K  61.9G    31K  /tank/home/mork
```

Note that `tank/home` is using 5GB of disk space, although the total amount of space referred to by `tank/home` and its descendents is much less than 5GB. The used space reflects the space reserved for `tank/home/bhall`. Reservations are considered in the used disk space calculation of the parent file system and do count against its quota, reservation, or both.

```
$ zfs set quota=5G pool/filesystem
$ zfs set reservation=10G pool/filesystem/user1
cannot set reservation for 'pool/filesystem/user1': size is greater than
available space
```

A dataset can use more disk space than its reservation, as long as unreserved space is available in the pool, and the dataset's current usage is below its quota. A dataset cannot consume disk space that has been reserved for another dataset.

Reservations are not cumulative. That is, a second invocation of `zfs set` to set a reservation does not add its reservation to the existing reservation. Rather, the second reservation replaces the first reservation. For example:

```
$ zfs set reservation=10G tank/home/bhall
$ zfs set reservation=5G tank/home/bhall
$ zfs get reservation tank/home/bhall
NAME             PROPERTY     VALUE   SOURCE
tank/home/bhall  reservation  5G      local
```

You can set a `refreservation` reservation to guarantee disk space for a dataset that does not include disk space consumed by snapshots and clones. This reservation is accounted for in the parent dataset's space used calculation, and counts against the parent dataset's quotas and reservations. For example:

```
$ zfs set refreservation=10g profs/prof1
$ zfs list
NAME                      USED  AVAIL  REFER  MOUNTPOINT
profs                    10.0G  23.2G    19K  /profs
profs/prof1                10G  33.2G    18K  /profs/prof1
```

You can also set a reservation on the same dataset to guarantee dataset space and snapshot space. For example:

```
$ zfs set reservation=20g profs/prof1
$ zfs list
NAME                      USED  AVAIL  REFER  MOUNTPOINT
profs                    20.0G  13.2G    19K  /profs
profs/prof1                10G  33.2G    18K  /profs/prof1
```

Regular reservations are accounted for in the parent's used space calculation.

In the preceding example, the smaller of the two quotas (10GB as compared to 20GB) is displayed in the `zfs list` output. To view the value of both quotas, use the `zfs get` command. For example:

```
$ zfs get reservation,refreserv profs/prof1
NAME         PROPERTY        VALUE        SOURCE
profs/prof1  reservation     20G          local
profs/prof1  refreservation  10G          local
```

If `refreservation` is set, a snapshot is only allowed if sufficient unreserved pool space exists outside of this reservation to accommodate the current number of *referenced* bytes in the dataset.

# Setting I/O Bandwidth Limits

Setting the size of a ZFS dataset can ensure an appropriate allocation of space in a configuration that contains multiple volumes to service different ZFS clients. However, ZFS clients of a specific dataset can still monopolize the system's bandwidth if the I/O operations within the dataset surpasses those operations in other datasets. Monopoly of bandwidth use effectively denies other ZFS clients of other datasets from accessing the data. By using the read and write limiting properties, you can assign limits to the I/O operations in datasets to provide bandwidth to all datasets for their respective clients to use.

- `writelimit` – Sets the maximum bytes per second that a dataset can write to disk
- `readlimit` – Sets the maximum bytes per second that a dataset can read from a disk
- `defaultwritelimit` – Sets the maximum bytes per second that the descendants of a dataset can write to disk
- `defaultreadlimit` – Sets the maximum bytes per second that the descendants of a dataset can read from a disk
- `effectivewritelimit` – Reports the maximum bytes per second that a dataset can write to disk
- `effectivereadlimit` – Reports the maximum bytes per second that a dataset can read from a disk

> **Note:**
>
> These values are not guaranteed bandwidth and the actual bandwidth may be limited by other factors including usage and limits set on other datasets in the hierarchy. Enforcement of these limits may be delayed by several seconds.

The default limits on the descendants of a dataset can be overwritten with the `writelimit` or `readlimit` properties. They can be set to any value, but the throughput on a descendant dataset will not be more than the rate of a parent dataset. The minimum value for these properties is 500K.

```
$ zfs get -r writelimit,defaultwritelimit,effectivewritelimit users/home
NAME                 PROPERTY             VALUE     SOURCE
users/home           writelimit           default   default
users/home           defaultwritelimit    none      default
users/home           effectivewritelimit  none      local
users/home/kaydo     writelimit           default   default
users/home/kaydo     defaultwritelimit    none      default
users/home/kaydo     effectivewritelimit  none      local
```

The `writelimit` or `readlimit` properties can be set to `none` to inherit the limit set on the parent dataset. Also they can be set to default to use the default limit set on the parent dataset.

**Example 7-5 Default Settings for Bandwidth Limiting Properties**

If a new dataset is created, it uses the bandwidth limits established by the parent dataset. In this example, the parent dataset had no bandwidth limiting properties set.

```
$ zfs get -r writelimit,defaultwritelimit,effectivewritelimit users/home
NAME                 PROPERTY             VALUE     SOURCE
users/home           writelimit           default   default
```

```
users/home          defaultwritelimit     none      default
users/home          effectivewritelimit   none      local
users/home/nneke    writelimit            default   default
users/home/nneke    defaultwritelimit     none      default
users/home/nneke    effectivewritelimit   none      local
```

In this example. the parents' `defaultwritelimit` properties was set to `500K`, so that is the effective write limit for the descendant dataset.

```
$ zfs get -r writelimit,defaultwritelimit,effectivewritelimit users/home
NAME                PROPERTY              VALUE     SOURCE
users/home          writelimit            1M        local
users/home          defaultwritelimit     500K      local
users/home          effectivewritelimit   1M        local
users/home/nneke    writelimit            default   default
users/home/nneke    defaultwritelimit     500K      inherited from users/home
users/home/nneke    effectivewritelimit   500K      local
```

**Example 7-6 Using the Bandwidth Limiting Properties From the Parent Dataset**

By default, descendant datasets use the bandwidth limiting values set in the parents' `defaultwritelimit` and `defaultreadlimit` properties. If you want to use the same write values as the parent dataset instead of the default settings, set the `writelimit` property for the descendant dataset to `none`. In this case, the effective write limit will be reported as the same as the parent datasets' `writelimit` property. In this example the effective write limit for the descendant dataset is `1M` which is the effective write limit of the parent, instead of `500K` which is the default write limit set in the parent dataset.

```
$ zfs set writelimit=none users/home/kaydo
$ zfs get -r writelimit,defaultwritelimit,effectivewritelimit users/home
NAME                PROPERTY              VALUE     SOURCE
users/home          writelimit            1M        local
users/home          defaultwritelimit     500K      local
users/home          effectivewritelimit   1M        local
users/home/kaydo    writelimit            none      local
users/home/kaydo    defaultwritelimit     500K      inherited from users/home
users/home/kaydo    effectivewritelimit   1M        local
```

In this example, the descendants' properties are limited by the write limit set by on the parent dataset. The descendant dataset will not be given higher bandwidth values than the parent.

```
$ zfs create -o writelimit=2M users/home/mork
$ zfs get -r writelimit,defaultwritelimit,effectivewritelimit users/home
NAME                PROPERTY              VALUE     SOURCE
users/home          writelimit            1M        local
users/home          defaultwritelimit     500K      local
users/home          effectivewritelimit   1M        local
users/home/mork     writelimit            2M        local
users/home/mork     defaultwritelimit     500K      inherited from users/home
users/home/mork     effectivewritelimit   1M        local
```

# Compressing ZFS File Systems

Compression is the process where data is stored using less disk space. The following compression algorithms are available:

- `gzip` - standard UNIX compression.
- `gzip-` *N* - selects a specific gzip level. `gzip-1` provides the fastest gzip compression. `gzip-9` provides the best data compression. `gzip-6` is the default.

- `lz4` - provides better compression with lower CPU overhead
- `lzjb` - optimized for performance while providing decent compression
- `zle` - zero length encoding is useful for datasets with large blocks of zeros

> **Note:**
>
> Currently, neither `lz4` or `gzip` compression is supported on root pools.

You can choose a specific compression algorithm by setting the compression ZFS property. To use the LZ4 algorithm, use a command like the following:

```
$ zfs set compress=lz4 pool/fs
```

# Encrypting ZFS File Systems

Encryption is the process where data is encoded for privacy and a key is needed by the data owner to access the encoded data. The benefits of using ZFS encryption are as follows:

- ZFS encryption is integrated with the ZFS command set. Like other ZFS operations, encryption operations such as key changes and rekey are performed online.
- You can use your existing storage pools as long as they are upgraded. You have the flexibility of encrypting specific file systems.
- Data is encrypted using AES (Advanced Encryption Standard) with key lengths of 128, 192, and 256 in the CCM and GCM operation modes.
- ZFS encryption uses the Oracle Solaris Cryptographic Framework, which gives it access to any available hardware acceleration or optimized software implementations of the encryption algorithms automatically.
- Currently, you cannot encrypt the ZFS root file system or other OS components, such as the `/var` directory, even if it is a separate file system.
- ZFS encryption is inheritable to descendent file systems.
- A regular user can create an encrypted file system and manage key operations if `create`, `mount`, `keysource`, `checksum`, and `encryption` permissions are assigned to him.

> **Note:**
>
> ZFS wrapping and data encryption keys use AES while Trusted Platform Module (TPM) support in Oracle Solaris 11 can only store RSA keys. Consequently, ZFS encryption can not use TPM as the root of trust for storing keys. As best practice, use a remote key management system instead of TPM, such as Oracle Key Management, Oracle Key Vault, or any third party product that supports the KMIP standard. For Oracle Key Manager documentation, see the Storage Encryption section in Tape Storage Products Documentation Library (https://docs.oracle.com/cd/F24623_01/index.html#crypto). For Oracle Key Vault documentation, see the Database Security section in https://docs.oracle.com/en/database/related-products.html.

You can set an encryption policy when a ZFS file system is created, but the policy cannot be changed. For example, the `tank/home/megr` file system is created with the encryption

property enabled. The default encryption policy is to prompt for a passphrase, which must be a minimum of 8 characters in length.

```
$ zfs create -o encryption=on tank/home/megr
Enter passphrase for 'tank/home/megr': xxxxxxx
Enter again: xxxxxxxx
```

Confirm that the file system has encryption enabled. For example:

```
$ zfs get encryption tank/home/megr
NAME              PROPERTY    VALUE        SOURCE
tank/home/megr  encryption  on           local
```

The default encryption algorithm is `aes-128-ccm` when a file system's encryption value is `on`.

A *wrapping key* is used to encrypt the actual data encryption keys. The wrapping key is passed from the `zfs` command, as in the above example when the encrypted file system is created, to the kernel. A wrapping key is either in a file (in raw or hex format) or it is derived from a passphrase.

The format and location of the wrapping key are specified in the `keysource` property as follows:

`keysource=`*`format`*`,`*`location`*

- *format* is one of the following:
  - `raw` – The raw key bytes
  - `hex` – A hexadecimal key string
  - `passphrase` – A character string that generates a key
- *location* is one of the following:
  - `prompt` – You are prompted for a key or a passphrase when the file system is created or mounted
  - `file:///`*filename* – The key or a passphrase file location in a file system
  - `pkcs11` – A URI describing the location of a key or a passphrase in a PKCS#11 token
  - `https://`*location* – The key or a passphrase file location on a secure server. Transporting key information in the clear using this method is not recommended. A `GET` on the URL returns just the key value or the passphrase, according to what was requested in the format part of the `keysource` property.

    When using an `https://` locator for the `keysource`, the certificate that the ZFS server presents must be one that is trusted by `libcurl` and OpenSSL. Add your own trust anchor or self signed certificate to the certificate store in `/etc/openssl/certs`. Place the PEM format certificate into the `/etc/certs/CA` directory and run the following command:

    ```
    $ svcadm refresh ca-certificates
    ```

If the `keysource` format is *passphrase*, then the wrapping key is derived from the passphrase. Otherwise, the `keysource` property value points to the actual wrapping key, as raw bytes or in hexadecimal format. You can specify that the passphrase is stored in a file or stored in a raw stream of bytes that are prompted for, which is likely only suitable for scripting.

When a file system's `keysource` property values identifies `passphrase`, then the wrapping key is derived from the passphrase using `PKCS#5 PBKD2` and a per file system randomly generated salt. This means that the same passphrase generates a different wrapping key if used on descendent file systems.

A file system's encryption policy is inherited by descendent file systems and cannot be removed. For example:

```
$ zfs snapshot tank/home/megr@now
$ zfs clone tank/home/megr@now tank/home/megr-new
Enter passphrase for 'tank/home/megr-new': xxxxxxx
Enter again: xxxxxxxx
$ zfs set encryption=off tank/home/megr-new
cannot set property for 'tank/home/megr-new': 'encryption' is readonly
```

If you need to copy or migrate encrypted or unencrypted ZFS file systems, then consider the following points:

- Currently, you cannot send an unencrypted dataset stream and receive it as an encrypted stream even if the receiving pool's dataset has encryption enabled.
- You can use the following commands to migrate unencrypted data to a pool/file system with encryption enabled:
  - `cp -r`
  - `find | cpio`
  - `tar`
  - `rsync`
- A replicated encrypted file system stream can be received into a encrypted file system and the data remains encrypted. For more information, see Sending and Receiving an Encrypted ZFS File System.

> **Note:**
>
> Although ZFS encrypted filesystems can restrict access to data at rest, that protection is lost when the filesystem is mounted. Users who can assume the root role or use the `sudo` command can have unconstrained access to these files. To add a layer of security, use file and process labeling to implement access control especially to sensitive files. See Chapter 3, Labeling Files for Data Loss Protection in *Securing Files and Verifying File Integrity in Oracle Solaris 11.4*.

## Changing an Encrypted ZFS File System's Keys

You can change an encrypted file system's wrapping key by using the `zfs key -c` command. The existing wrapping key must have been loaded first, either at boot time or by explicitly loading the file system key (`zfs key -l`) or by mounting the file system (`zfs mount` *filesystem*). For example:

```
$ zfs key -c tank/home/megr
Enter new passphrase for 'tank/home/megr': xxxxxxxx
Enter again: xxxxxxxx
```

In the following example, the wrapping key is changed and the `keysource` property value is changed to specify that the wrapping key comes from a file.

```
$ zfs key -c -o keysource=raw,file:///media/stick/key
tank/home/megr
```

The data encryption key for an encrypted file system can be changed by using the `zfs key -K` command, but the new encryption key is only used for newly written data. This feature can

be used to provide compliance with NIST 800-57 guidelines on a data encryption key's time limit. For example:

```
$ zfs key -K tank/home/megr
```

In the above example, the data encryption key is not visible nor is it directly managed by you. In addition, you need the `keychange` delegation to perform a key change operation.

The following encryption algorithms are available:

- `aes-128-ccm`, `aes-192-ccm`, `aes-256-ccm`
- `aes-128-gcm`, `aes-192-gcm`, `aes-256-gcm`

The ZFS `keysource` property identifies the format and location of the key that wraps the file system's data encryption keys. For example:

```
$ zfs get keysource tank/home/megr
NAME              PROPERTY   VALUE              SOURCE
tank/home/megr  keysource  passphrase,prompt  local
```

The ZFS `rekeydate` property identifies the date of the last `zfs key -K` operation. For example:

```
$ zfs get rekeydate tank/home/megr
NAME              PROPERTY   VALUE                  SOURCE
tank/home/megr  rekeydate  Wed Jul 25 16:54 2012  local
```

If an encrypted file system's `creation` and `rekeydate` properties have the same value, the file system has never been rekeyed by an `zfs key -K` operation.

## Managing ZFS Encryption Keys

ZFS encryption keys can be managed in different ways, depending on your needs, either on the local system or remotely, if a centralized location is needed.

- **Locally** – The above examples illustrate that the wrapping key can be either a passphrase prompt or a raw key that is stored in a file on the local system.
- **Remotely** – Key information can be stored remotely by using a centralized key management system like Oracle Key Manager or by using a web service that supports a simple GET request on an http or https URI. Oracle Key Manager key information is accessible to an Oracle Solaris system by using a PKCS#11 token.

For information about managing ZFS encryption keys, see How to Manage ZFS Data Encryption (https://www.oracle.com/technical-resources/articles/solaris/how-to-manage-zfs-encryption.html)

For information about using Oracle Key Manager to manage key information, see:

https://docs.oracle.com/cd/E50985_03/index.html

## Delegating ZFS Key Operation Permissions

Review the following permission descriptions for delegating key operations:

- Loading or unloading a file system key by using the `zfs key -l` and `zfs key -u` commands require the `key` permission. In most cases, you will need the `mount` permission as well.

- Changing a file system key by using the `zfs key -c` and `zfs key -K` commands require the `keychange` permission.

Consider delegating separate permissions for key use (load or unload) and key change, which allows you to have a two-person key operation model. For example, determine which users can use the keys verses which users can change them. Or, both users need to be present for a key change. This model also allows you to build a key escrow system.

## Mounting an Encrypted ZFS File System

Review the following considerations when attempting to mount an encrypted ZFS file system:

- If an encrypted file system key is not available during boot time, the file system is not mounted automatically. For example, a file system with an encryption policy set to `passphrase,prompt` will not mount during boot time because the boot process is not interrupted to prompt for a passphrase.
- If you want to mount a file system with an encryption policy set to `passphrase,prompt` at boot time, you will need to either explicitly mount it with the `zfs mount` command and specify the passphrase or use the `zfs key -l` command to be prompted for the key after the system is booted.

  For example:

```
$ zfs mount -a
Enter passphrase for 'tank/home/megr': xxxxxxxx
Enter passphrase for 'tank/home/ws': xxxxxxxx
Enter passphrase for 'tank/home/mork': xxxxxxxx
```

- If an encrypted file system's `keysource` property points to a file in another file system, the mount order of the file systems can impact whether the encrypted file system is mounted at boot, particularly if the file is on removable media.

## Upgrading Encrypted ZFS File Systems

Before you upgrade an Oracle Solaris 11 system to Oracle Solaris 11.1, ensure that your encrypted file systems are mounted. Mount the encrypted file systems and provide the passphrases, if prompted.

```
$ zfs mount -a
Enter passphrase for 'pond/jaust': xxxxxxxx
Enter passphrase for 'pond/rori': xxxxxxxx
$ zfs mount | grep pond
pond                            /pond
pond/jaust                      /pond/jaust
pond/rori                       /pond/rori
```

Then, upgrade the encrypted file systems.

```
$ zfs upgrade -a
```

If you attempt to upgrade encrypted ZFS file systems that are unmounted, a message similar to the following is displayed:

```
$ zfs upgrade -a
cannot set property for 'pond/jaust': key not present
```

In addition, the `zpool status` output might show corrupted data.

```
$ zpool status -v pond
...
```

```
pond/jaust:<0x1>
pond/rori:<0x1>
```

If the above errors occur, remount the encrypted file systems as directed above. Then, scrub and clear the pool errors.

```
$ zpool scrub pond
$ zpool clear pond
```

For more information about upgrading file systems, see Upgrading ZFS File Systems.

# Interactions Between ZFS Compression, Deduplication, and Encryption Properties

Review the following considerations when using the ZFS compression, deduplication, and encryption properties:

- When a file is written, the data is compressed, encrypted, and the checksum is verified. Then, the data is deduplicated, if possible.
- When a file is read, the checksum is verified and the data is decrypted. Then, the data is decompressed, if required.
- If the `dedup` property is enabled on an encrypted file system that is also cloned and the `zfs key -K` or `zfs clone -K` commands have not been used on the clones, data from all the clones will be deduplicated, if possible.

# Examples of Encrypting ZFS File Systems

### Example 7-7 Encrypting a ZFS File System by Using a Raw Key

In the following example, an `aes-256-ccm` encryption key is generated by using the `pktool` command and is written to a file, `/kaydo.file`.

```
$ pktool genkey keystore=file outkey=/kaydokey.file keytype=aes keylen=256
```

Then, the `/kaydokey.file` is specified when the `tank/home/kaydo` file system is created.

```
$ zfs create -o encryption=aes-256-ccm -o keysource=raw,file:///kaydokey.file \
tank/home/kaydo
```

### Example 7-8 Encrypting a ZFS File System With a Different Encryption Algorithm

You can create a ZFS storage pool and have all the file systems in the storage pool inherit an encryption algorithm. In this example, the `users` pool is created and the `users/home` file system is created and encrypted by using a passphrase. The default encryption algorithm is `aes-128-ccm`.

Then, the `users/home/mork` file system is created and encrypted by using the `aes-256-ccm` encryption algorithm.

```
$ zpool create -O encryption=on users mirror c0t1d0 c1t1d0 mirror c2t1d0 c3t1d0
Enter passphrase for 'users': xxxxxxxx
Enter again: xxxxxxxx
$ zfs create users/home
$ zfs get encryption users/home
NAME        PROPERTY    VALUE        SOURCE
users/home  encryption  on           inherited from users
$ zfs create -o encryption=aes-256-ccm users/home/mork
```

```
$ zfs get encryption users/home/mork
NAME               PROPERTY    VALUE        SOURCE
users/home/mork    encryption  aes-256-ccm  local
```

### Example 7-9 Cloning an Encrypted ZFS File System

If the clone file system inherits the `keysource` property from the same file system as its origin snapshot, then a new `keysource` is not necessary, and you are not prompted for a new passphrase if `keysource=passphrase,prompt`. The same `keysource` is used for the clone. For example:

By default, you are not prompted for a key when cloning a descendent of an encrypted file system.

```
$ zfs create -o encryption=on tank/ws
Enter passphrase for 'tank/ws': xxxxxxxx
Enter again: xxxxxxxx
$ zfs create tank/ws/fs1
$ zfs snapshot tank/ws/fs1@snap1
$ zfs clone tank/ws/fs1@snap1 tank/ws/fs1clone
```

If you want to create a new key for the clone file system, use the `zfs clone -K` command.

If you clone an encrypted file system rather than a descendent encrypted file system, you are prompted to provide a new key. For example:

```
$ zfs create -o encryption=on tank/ws
Enter passphrase for 'tank/ws': xxxxxxxx
Enter again: xxxxxxxx
$ zfs snapshot tank/ws@1
$ zfs clone tank/ws@1 tank/ws1clone
Enter passphrase for 'tank/ws1clone': xxxxxxxx
Enter again: xxxxxxxx
```

### Example 7-10 Sending and Receiving an Encrypted ZFS File System

In the following example, the `tank/home/megr@snap1` snapshot is created from the encrypted `/tank/home/megr` file system. Then, the snapshot is sent to `bpool/snaps`, with the encryption property enabled so the resulting received data is encrypted. However, the `tank/home/megr@snap1` stream is not encrypted during the send process.

```
$ zfs get encryption tank/home/megr
NAME              PROPERTY    VALUE        SOURCE
tank/home/megr  encryption  on           local
$ zfs snapshot tank/home/megr@snap1
$ zfs get encryption bpool/snaps
NAME          PROPERTY    VALUE        SOURCE
bpool/snaps  encryption  on           inherited from bpool
$ zfs send tank/home/megr@snap1 | zfs receive bpool/snaps/megr
$ zfs get encryption bpool/snaps/megr
NAME                    PROPERTY    VALUE        SOURCE
bpool/snaps/megr        encryption  on           inherited from bpool
```

In this case, a new key is automatically generated for the received encrypted file system.

# Retaining Files on Your ZFS File System

Using a file retention policy enables you to specify a uniform rule to indicate how long to retain your organization's records. Ensure that your policy establishes the retention period for your data, which relies on the impact and importance of each document type.

The policy dictates the retention period for all your confidential and private official documents such as email, client correspondence, customer records, employee records, contracts, and financial records.

Without creating a retention policy, you might face stress or face legal complications if you destroy some documents too soon.

The Oracle Solaris 11.4 software introduces the ZFS file retention feature that enables you to implement your organization's file retention policy. You can retain files only on a ZFS file system that has the file retention feature enabled.

You can retain a regular file (not a directory, link, special file, and so on) for a specified retention period. During the retention period, the retained file is read-only and cannot be modified or deleted. When the retention period ends, you can delete a retained file. However, you cannot modify that file, even after the retention period ends.

The shadow migration feature correctly handles retained files and migrates them with the retention period property values intact.

This section covers the following topics:

- Creating a ZFS File System With File Retention
- ZFS File Retention Properties
- Retaining Your Files
- Retaining Zero-Length Files
- Enabling Automatic File Retention
- File Retention Restrictions

For more information about the ZFS file retention feature, see the `zfs`(8) and `zpool`(8) man pages.

## Creating a ZFS File System With File Retention

You must enable file retention on a ZFS file system when you create it. By default, file retention is disabled on ZFS file systems.

During the ZFS file system creation process, you must specify the file retention policy:

```
zfs create -o retention.policy=policy
      pool/fs
```

Specify one of the following policies as the `retention.policy` property value:

- `privileged` - Permits a process with the `FILE_RETENTION_OVERRIDE` privilege to override retention protections and delete files. Note that this privilege does not permit you to modify retained files.

  You can destroy the file system and pool without requiring additional privileges if the contained file systems use the privileged retention policy or have file retention disabled.

- `mandatory` - Prevents you from deleting a retained file until the retention period ends.

  The `mandatory` policy's protection extends to the file system and pool. As a result, the file system and pool cannot be destroyed until the retention period of all files in the file system and pool have expired. A file system that uses the `mandatory` retention policy also protects its ancestors and clone descendants from being destroyed.

Note that after you set the `retention.policy` property on the ZFS file system, you cannot change the policy value or disable the file retention feature.

A retained file system preserves the full path name of each retained file, which ensures that you cannot hide a directory's location and cannot change any meaning that is conveyed by the retained file's path.

## ZFS File Retention Properties

The ZFS file retention feature uses properties to describe the file retention policy of your file system. For a description of each property, see the `zfs`(8) man page.

The following `zfs get` example output shows the file retention properties and their values:

```
# zfs get -e retention.all retain/mand
NAME         PROPERTY                      VALUE      SOURCE
retain/mand  retention.period.default      none       -
retain/mand  retention.period.deletegrace  60s        -
retain/mand  retention.period.grace        60s        -
retain/mand  retention.period.max          5y         -
retain/mand  retention.period.min          none       -
retain/mand  retention.policy              mandatory  -
retain/mand  retention.policy.changeacl    off        -
retain/mand  retention.policy.onexpiry     off        -
retain/mand  retention.status.expiry       -          -
retain/mand  retention.status.files        0          -
```

You can change the following file retention properties from these default values:

- `retention.period.min=0`
- `retention.period.max=5years`
- `retention.period.default=0`
- `retention.period.grace=0`
- `retention.period.deletegrace=0`
- `retention.policy=off`
- `retention.policy.changeacl=off`
- `retention.policy.onexpiry=off`

> **Note:**
>
> Do not use the `m` unit to specify a value in minutes, as this unit refers to months. Instead, specify the minutes as seconds such as 120s for two minutes.

The `retention.status.files` property shows the count of retained files.

The `retention.status.expiry` property shows the latest-expiring retention timestamp of a file. If that time has passed, the property value appends `(expired)` to the expiration timestamp. The `retention.status.expiry` value depends on how you retain the file, as follows:

- Running the `touch -R` or `touch -a` command with a date and time specifies the date and time at which the retention period expires.

- Running the `touch -R` or `touch -a` command without a date and time specifies a retention period of the current date and time plus the `retention.period.default` property value. This method is also used when you remove all write permissions from the file or set the `readonly` system attribute for the file.
- Enabling automatic retention by setting the `retention.period.grace` value to a positive integer specifies a retention period to the last time the file was modified (`mtime`) plus the `retention.period.grace` property value and the `retention.period.default` property value.

The `retention.policy.onexpiry` property specifies what occurs when the retention time of a file (`rtime`) expires. The following values are valid:

- `off`: After a file's retention period expires, the file remains. Note that the file might be deleted by a process that has the appropriate privileges. This is the default value.
- `delete`: Deletes a retained file automatically after the retention period expires.
- `hold`: Treats a file that has an expired retention as if the retention period has not expired. As a result, the ZFS file retention feature continues to block deletions. When set to `hold`, a file system that has a mandatory retention policy and its pool are blocked from destruction.

The `retention.policy.changeacl` property enables you to change the file permissions and ACL, other than write, on a retained file. The following values are valid:

- `on`: Enables you to change file permissions and ACL, except for write, on a retained file.
- `off`: Prevents you from changing file permissions and ACL on a retained file. This is the default value.

The `retention.period.deletegrace` property enables you to delay the deletion of a retained file by a specified amount of time. The default value is `0`. This property depends on the `retention.policy.onexpiry` property being set to `delete`. The property value must be less than 100 years.

## Retaining Your Files

You cannot remove a retained file until its retention period expires. You can use the default retention period or specify your own retention period a the time that you retain a file.

Use one of the following methods to specify the retention period for a file:

- `rtime` property - Specify the date and time at which you want the retention period to end in one of the following ways:
  - `touch -R` *filename* - Changes the retention period of the specified file to the current date and time plus the default retention period.

    If you use the `touch -R` command to specify a date and time, the specified value becomes the end of the retention period.

    You can use the `touch -R` command to extend the retention period of a retained file by specifying a date and time in the future. You can also use the `touch -t` and `touch -f` commands to specify a future date and time. Note that you cannot shorten the retention period of a retained file.

    Use this command only when the ZFS file system is local to the Oracle Solaris system.

    You can specify the retention period for a file by using the `touch` command. These commands enable you to set the `atime` property value to a future date and time before you make the file read-only:

    * `touch -R` *MMDDhhmm*`[`*YY*`]` *filename*
    * `touch -a` *MMDDhhmm*`[`*YY*`]` *filename*

    > **Note:**
    >
    > If you do not specify an `atime` property value, the file's retention period is specified by the `retention.period.default` property value.

  – `chmod a-w` *filename* or `chmod ugo-w` *filename* - Removes all write permissions from the file, which triggers file retention.

    These commands use the current date and time plus the default retention period unless `atime` is set to a future date and time. In that case, these commands use the `atime` value.

    Use these commands only when the ZFS file system is local or NFS mounted.

  – `chmod S+cR` *filename* or `chmod S+vreadonly` *filename* - Sets the `readonly` file attribute on the file over SMB, which triggers file retention.

    These commands use the current date and time plus the default retention period unless `atime` is set to a future date and time. In that case, these commands use the `atime` value.

    When a file's retention period ends, the `readonly` attribute is removed. At that time, you can retain the file again by specifying a new retention period.

- `min` and `max` ZFS properties - Specifies the minimum and maximum values that limit the retention period.

  If you do not specify a time with the `touch` command, remove write permissions, or set the `readonly` attribute on the file, files are retained for the default retention period.

  The `retention.period.min` and `retention.period.max` property values serve as limits on both the default retention period and for how long you can use `touch -R` to retain a file.

  Alternately, you can use the access time (`atime`) as the retention period. When you retain a file, its retention period is restricted to a range between the `min` and `max` property values. So, if a retention period that exceeds the range, the period is limited by the `min` and `max` property values.

  The `atime` that you set on a file by using `touch -a` command adheres to the time range restrictions only if its retained `atime` value is set to `off`. For example:

  ```
  # zfs set atime=off filesystem
  ```

  Optionally, using the `min` and `max` method automatically retains files that have remained unmodified for the default retention period.

  You can use the `touch -a` and `touch -R` commands to retain a file in a retained ZFS file system. When run on file systems that have file retention disabled, `touch -a` sets the `atime` property value and `touch -R` generates an error.

## Retaining Zero-Length Files

The ZFS file retention feature treats zero-length files differently than other regular files.

When you retain a zero-length file, the file sets the `appendonly` attribute. If you retain a file that has the `appendonly` attribute set, the file remains append-only.

You can add or remove write permissions from a retained zero-length file or from a retained file that has the `appendonly` attribute set.

If you remove all write permissions, the file becomes a typical retained file, which sets the `readonly` attribute and unsets the `appendonly` attribute. You can achieve the same result by setting the `readonly` attribute or by unsetting the `appendonly` attribute.

## Enabling Automatic File Retention

You can configure automatic file retention on a retained ZFS file system by setting the `retention.period.grace` property value to a non-zero integer. When enabled, any file that has not been modified for the grace period is retained automatically for the default retention period.

Note that when you enable automatic file retention, you cannot later disable it.

Also, you cannot increase the `retention.period.grace` property value after you enable automatic retention.

Dataset and pool protections are extended automatically upon each write and upon each mount. The new retention period becomes the current date and time plus the `retention.period.grace` property value and the `retention.period.default` property value. This action presumes that the file just written must be retained.

## File Retention Restrictions

The ZFS file retention feature has the following restrictions:

- You cannot rename a retained file or rename any part of that file's path. Note that you can rename a directory only if the directory is empty.
- You cannot roll back any dataset that uses the `mandatory` retention policy even if you use the `zfs rollback -F` command.
- No privilege exists that permits you to destroy a file system or pool that has unexpired retained files when the file system uses the `mandatory` retention policy.

# Migrating ZFS File Systems

To migrate a local or remote ZFS or UFS file system to a target ZFS file system, use shadow migration. The target file system is also called the shadow file system.

Use the following commands to manage shadow migration:

- The `shadowadm` command stops, resumes, or cancels shadow migration.
- The `shadowstat` command with its options monitors migrations running on the system. Use the `shadowstat` command without options to monitor the progress of migrations. The displayed information is continuously updated until you type Ctrl-C.

  The command's `-E` and `-e` options are particularly useful.

  – To list all currently running migrations and identify those that could not be completed because of errors, use the `-E` option.

  – To list a specific migration and check if errors are causing the migration to fail, use the `-e` option.

For an example that shows how these commands are used, see Starting and Monitoring File System Migrations.

> **Caution:**
>
> When migrating file systems, observe the following rules:
>
> - Do not add or remove data from the file system while it is being migrated. Otherwise, those changes are excluded from migration.
> - Do not change the `mountpoint` property of the shadow file system while migration is in progress.

## How to Migrate a File System to a ZFS File System

1. **If you are migrating data from a remote NFS server, confirm that the name service information is accessible on both remote and local systems.**

   For a large migration using NFS, you might consider doing a test migration of a subset of the data to ensure that the UID, GUID, and ACL information migrates correctly.

2. **If necessary, install the shadow-migration package on the target system.**

   ```
   $ pkg install shadow-migration
   ```

3. **Enable the shadowd service.**

   ```
   $ svcadm enable shadowd
   ```

4. **Set the local or remote file system to be migrated to read-only.**

   - If you are migrating a local ZFS file system, set it to read-only. For example:

     ```
     $ zfs set readonly=on tank/home/data
     ```

   - If you are migrating a remote file system, share it as read-only. For example:

     ```
     $ share -F nfs -o ro /export/home/ufsdata
     ```

5. **Create the target file system while setting the shadow file to the file system to be migrated.**

   > **Note:**
   >
   > The new target ZFS file system must be completely empty. Otherwise, migration will not start.

   Specify the `shadow` setting depending on the type of system you are migrating.

   - If you are migrating a local file system, specify the source path.

     For example:

     ```
     $ zfs create -o shadow=file:///west/home/data users/home/shadow
     ```

   - If you are migrating a NFS file system. specify the source host name and path.

     For example:

     ```
     $ zfs create -o shadow=nfs://neo/export/home/ufsdata users/home/shadow2
     ```

6. **To check the progress of the migration, issue the `shadowstat` command.**

   For examples of how to monitor migrations, see Starting and Monitoring File System Migrations.

> **Note:**
>
> Migrating file system data over NFS can be slow, depending on your network bandwidth. If the system is rebooted during migration, the migration continues after the system boot completes.

**Example 7-11 Starting and Monitoring File System Migrations**

In this example, multiple migrations are initiated. The `shadowadm` command lists ongoing migrations while the `shadowstat` command monitors their progress.

```
$ zfs create -o shadow=nfs://system2/rpool/data/jsmith/archive rpool/data/copyarchive
$ shadowadm list
PATH                                        STATE
/rpool/data/copyarchive                     ACTIVE

$ zfs create -o shadow=nfs://system2/rpool/data/jsmith/datalogs rpool/data/logcopy
$ shadowadm list
PATH                                        STATE
/rpool/data/copyarchive                     ACTIVE
/rpool/data/logcopy                         ACTIVE

$ shadowstat
                                  EST
                          BYTES   BYTES           ELAPSED
DATASET                   XFRD    LEFT    ERRORS  TIME
rpool/data/copyarchive    34.4M   3.37G   -       00:00:36
rpool/data/logcopy        1.12K   155K    1       (completed)Errors are detected.
rpool/data/copyarchive    34.5M   3.37G   -       00:00:37
rpool/data/logcopy        1.12K   155K    1       (completed)
rpool/data/copyarchive    35.0M   3.37G   -       00:00:38
rpool/data/logcopy        1.12K   155K    1       (completed)
rpool/data/copyarchive    35.2M   3.37G   -       00:00:39
rpool/data/logcopy        1.12K   155K    1       (completed)
^C
```

The previous `shadowstat` output indicates errors in the migration to `rpool/data/logcopy`.

The following output from the `shadowstat -E` and `shadowstate -e` commands show that migration to `rpool/data/logcopy` could not be completed because socket migration is not supported. The `shadowadm` command cancels the migration.

```
$ shadowstat -E
rpool/data/copyarchive:
No errors encountered.
rpool/data/logcopy:
PATH                                                ERROR
errdir/cups-socket                                  Operation not supported

$ shadowstat -e /rpool/data/logcopy
rpool/data/logcopy:
PATH                                                ERROR
errdir/cups-socket                                  Operation not supported

$ shadowadm cancel /rpool/data/logcopy
```

The following output shows information about the migration to `rpool/data/copyarchive`, which continues toward completion.

```
$ shadowadm list
PATH                                        STATE
/rpool/data/copyarchive                     ACTIVE$ shadowstat
                                       EST
                                BYTES  BYTES           ELAPSED
DATASET                         XFRD   LEFT    ERRORS  TIME
rpool/data/copyarchive          251M   3.16G   -       00:01:27
rpool/data/copyarchive          251M   3.16G   -       00:01:28
rpool/data/copyarchive          252M   3.16G   -       00:01:29
^C

$ shadowstat
No migrations in progress.
$ shadowadm list
$ exit
```

# How to Migrate SMB Filesystems

To migrate SMB filesystems, observe the following requirements:

- If Active Directory is used, then both the source system and the target system must be in the same AD domain.
- Unlike NFS source filesystems, SMB systems require authentication to grant access. Therefore, the target system must be aware of the user account on the source system. Ensure also that the user has backup and restore privileges on the source system.
- The SMB source must be using the SMB 2.0 protocol.

1. **Configure the same SMB user account on the target system to enable authentication to be processed between the source and target systems.**

   Ensure that the password is persistent in the target system:

   - If the domain controller is configured to allow all NT Lan Manager (NTLM) pass-through authentication requests within the domain, use the `smbadm add-key` command to create the persistent password.
   - If the domain controller is configured to restrict all NTLM pass-through authentication requests, enable Kerberos caching. Then, use the `kinit` command to create a persistent password.

2. **Set the SMB source filesystem to have read-only permissions during the migration.**
3. **Create the target file system while setting the shadow file to the file system to be migrated.**

   > **Note:**
   >
   > The new target ZFS file system must be completely empty. Otherwise, migration will not start.

   ```
   $ zfs create -o shadow=smb://user@host/path target
   ```

4. **To check the progress of the migration, use the shadowstat command.**

# Upgrading ZFS File Systems

If you have ZFS file systems from a previous Oracle Solaris release, you can upgrade your file systems with the `zfs upgrade` command to take advantage of the file system features in the current release. In addition, this command notifies you when your file systems are running older versions.

For example, this file system is at the current version 5.

```
$ zfs upgrade
This system is currently running ZFS filesystem version 5.

All filesystems are formatted with the current version.
```

Use this command to identify the features that are available with each file system version.

```
$ zfs upgrade -v
The following filesystem versions are supported:

VER  DESCRIPTION
---  --------------------------------------------------------
1    Initial ZFS filesystem version
2    Enhanced directory entries
3    Case insensitive and File system unique identifier (FUID)
4    userquota, groupquota properties
5    System attributes
6    Multilevel file system support

For more information about a particular version, including supported releases,
see the ZFS Administration Guide.
```

For information about upgrading encrypted file systems, see Upgrading Encrypted ZFS File Systems.

8

# Working With Oracle Solaris ZFS Snapshots and Clones

This chapter describes how to create and manage Oracle Solaris ZFS snapshots and clones. It also provides information about saving snapshots.

The chapter covers the following topics:

- Overview of ZFS Snapshots.
- Creating and Destroying ZFS Snapshots.
- Displaying and Accessing ZFS Snapshots.
- Rolling Back a ZFS Snapshot.
- Overview of ZFS Clones.
- Creating a ZFS Clone.
- Destroying a ZFS Clone.
- Replacing a ZFS File System With a ZFS Clone.
- Saving, Sending, and Receiving ZFS Data.
- Monitoring ZFS Pool Operations

## Overview of ZFS Snapshots

A *snapshot* is a read-only copy of a file system or volume. Snapshots can be created almost instantly, and they initially consume no additional disk space within the pool. However, as data within the active dataset changes, the snapshot consumes disk space by continuing to reference the old data, thus preventing the disk space from being freed.

A *clone* is a writable volume or file system whose initial contents are the same as the dataset from which it was created. Clones can be created only from a snapshot.

ZFS snapshots include the following features:

- They persist across system reboots.
- The theoretical maximum number of snapshots is $2^{64}$.
- Snapshots use no separate backing store. Snapshots consume disk space directly from the same storage pool as the file system or volume from which they were created.
- Recursive snapshots are created quickly as one atomic operation. The snapshots are created together (all at once) or not created at all. The benefit of atomic snapshot operations is that the snapshot data is always taken at one consistent time, even across descendant file systems.

Snapshots of volumes cannot be accessed directly, but they can be cloned, backed up, rolled back to, and so on. For information about backing up a ZFS snapshot, see Saving, Sending, and Receiving ZFS Data.

This section covers the following topics:

- Creating and Destroying ZFS Snapshots
- Displaying and Accessing ZFS Snapshots
- Rolling Back a ZFS Snapshot

> **Note:**
>
> Certain snapshot operations can be set by using the Desktop's Time Slider. See Using Time Slider.

# Creating and Destroying ZFS Snapshots

You create snapshots by using the `zfs snapshot` or the `zfs snap` command, which takes as its only argument the name of the snapshot to create. The snapshot name uses one of the following conventions:

- *filesystem@snapname*
- *volume@snapname*

The snapshot name must satisfy the naming requirements in Naming ZFS Components.

The following example creates a snapshot of `system1/home/kaydo` that is named `friday`.

```
$ zfs snapshot system1/home/kaydo@friday
```

To create snapshots for all descendant file systems, use the `rr` option. For example:

```
$ zfs snapshot -r system1/home@snap1
$ zfs list -t snapshot -r system1/home
NAME                        USED  AVAIL   REFER  MOUNTPOINT
system1/home@snap1             0      -   2.11G  -
system1/home/kaydo@snap1       0      -    115M  -
system1/home/glori@snap1       0      -   2.00G  -
system1/home/hsolo@snap1       0      -   2.00G  -
system1/home/cpark@snap1       0      -   57.3M  -
```

Snapshots have no modifiable properties, nor can dataset properties be applied to a snapshot. For example:

```
$ zfs set compression=on system1/home/kaydo@friday
cannot set property for 'system1/home/kaydo@friday':
this property can not be modified for snapshots
```

To destroy snapshots, use the `zfs destroy` command. For example:

```
$ zfs destroy system1/home/kaydo@friday
```

You cannot destroy a dataset if snapshots of the dataset exist. For example:

```
$ zfs destroy system1/home/kaydo
cannot destroy 'system1/home/kaydo': filesystem has children
use '-r' to destroy the following datasets:
system1/home/kaydo@tuesday
system1/home/kaydo@wednesday
system1/home/kaydo@thursday
```

In addition, if clones have been created from a snapshot, then you must destroy them before you can destroy the snapshot.

For more information about the `destroy` subcommand, see How to Destroy a ZFS File System.

## Holding ZFS Snapshots

Older snapshots are sometimes inadvertently destroyed due to different automatic snapshot or data retention policies. If a removed snapshot is part of an ongoing ZFS send and receive operation, then the operation might fail. To avoid this scenario, consider placing a hold on a snapshot.

*Holding* a snapshot prevents it from being destroyed. In addition, this feature allows a snapshot with clones to be deleted pending the removal of the last clone by using the `zfs destroy -d` command. Each snapshot has an associated *user-reference count*, which is initialized to zero. This count increases by 1 whenever a hold is put on a snapshot and decreases by 1 whenever a hold is released.

In the previous Oracle Solaris release, you could destroy a snapshot only by using the `zfs destroy` command if it had no clones. In this Oracle Solaris release, the snapshot must also have a zero user-reference count.

You can hold a snapshot or set of snapshots. For example, the following syntax puts a hold tag, `keep`, on `system1/home/kaydo/snap@1`:

```
$ zfs hold keep system1/home/kaydo@snap1
```

To recursively hold the snapshots of all descendant file systems, use the `-r` option. For example:

```
$ zfs snapshot -r system1/home@now
$ zfs hold -r keep system1/home@now
```

This syntax adds a single reference, `keep`, to the given snapshot or set of snapshots. Each snapshot has its own tag namespace and hold tags must be unique within that space. If a hold exists on a snapshot, attempts to destroy that held snapshot by using the `zfs destroy` command will fail. For example:

```
$ zfs destroy system1/home/kaydo@snap1
cannot destroy 'system1/home/kaydo@snap1': dataset is busy
```

To destroy a held snapshot, use the `-d` option. For example:

```
$ zfs destroy -d system1/home/kaydo@snap1
```

To display a list of held snapshots, use the `zfs holds` command. For example:

```
$ zfs holds system1/home@now
NAME              TAG   TIMESTAMP
system1/home@now  keep  Fri Aug  3 15:15:53 2012

$ zfs holds -r system1/home@now
NAME                    TAG   TIMESTAMP
system1/home/kaydo@now  keep  Fri Aug  3 15:15:53 2012
system1/home/glori@now  keep  Fri Aug  3 15:15:53 2012
system1/home/hsolo@now  keep  Fri Aug  3 15:15:53 2012
system1/home/cpark@now  keep  Fri Aug  3 15:15:53 2012
system1/home@now        keep  Fri Aug  3 15:15:53 2012
```

To release a hold on a snapshot or set of snapshots, use the `zfs release` command. For example:

```
$ zfs release -r keep system1/home@now
```

If the snapshot is released, the snapshot can be destroyed by using the `zfs destroy` command. For example:

```
$ zfs destroy -r system1/home@now
```

Two properties identify snapshot hold information.

- The `destroyer` property is set to `on` if the snapshot has been marked for deferred destruction by using the `zfs destroy -d` command. Otherwise, the property is set to `off`.
- The `userrefs` property is set to the number of holds on this snapshot.

## Renaming ZFS Snapshots

You can rename snapshots, but only within the same pool and dataset from which they were created. For example:

```
$ zfs rename system1/home/kaydo@snap1 system1/home/kaydo@today
```

You can also use the following shortcut syntax:

```
$ zfs rename system1/home/kaydo@snap1 today
```

The following snapshot `rename` operation is not supported because the target pool and file system name are different from the pool and file system where the snapshot was created:

```
$ zfs rename system1/home/kaydo@today pool/home/kaydo@saturday
cannot rename to 'pool/home/kaydo@today': snapshots must be part of same
dataset
```

You can recursively rename snapshots by using the `zfs rename -r` command. For example:

```
$ zfs list -t snapshot -r users/home
NAME                         USED  AVAIL  REFER  MOUNTPOINT
users/home@now              23.5K      -  35.5K  -
users/home@yesterday            0      -    38K  -
users/home/glori@yesterday      0      -  2.00G  -
users/home/hsolo@yesterday      0      -  1.00G  -
users/home/nneke@yesterday      0      -  2.00G  -
$ zfs rename -r users/home@yesterday @2daysago
$ zfs list -t snapshot -r users/home
NAME                         USED  AVAIL  REFER  MOUNTPOINT
users/home@now              23.5K      -  35.5K  -
users/home@2daysago             0      -    38K  -
users/home/glori@2daysago       0      -  2.00G  -
users/home/hsolo@2daysago       0      -  1.00G  -
users/home/nneke@2daysago       0      -  2.00G  -
```

# Displaying and Accessing ZFS Snapshots

By default, snapshots no longer appear in the `zfs list` output. You must use the `zfs list -t snapshot` command to display snapshot information. You can also enable the `listsnapshots` pool property instead. For example:

```
$ zpool get listsnapshots system1
NAME     PROPERTY       VALUE      SOURCE
system1  listsnapshots  off        default
$ zpool set listsnapshots=on system1
```

```
$ zpool get listsnapshots system1
NAME     PROPERTY       VALUE      SOURCE
system1  listsnapshots  on         local
```

Snapshots of file systems are placed in the `.zfs/snapshot` directory within the root of the file system. For example, if `system1/home/kaydo` is mounted on `/home/kaydo`, then the `system1/home/kaydo@thursday` snapshot data is accessible in the `/home/kaydo/.zfs/snapshot/thursday` directory.

```
$ ls /system1/home/kaydo/.zfs/snapshot
thursday   tuesday    wednesday
```

The following examples shows how to list snapshots.

```
$ zfs list -t snapshot -r system1/home
NAME                           USED  AVAIL  REFER  MOUNTPOINT
system1/home/kaydo@tuesday      45K      -  2.11G  -
system1/home/kaydo@wednesday    45K      -  2.11G  -
system1/home/kaydo@thursday       0      -  2.17G  -
```

The following example shows how to list snapshots that were created for a particular file system.

```
$ zfs list -r -t snapshot -o name,creation system1/home
NAME                           CREATION
system1/home/kaydo@tuesday     Fri Aug  3 15:18 2012
system1/home/kaydo@wednesday   Fri Aug  3 15:19 2012
system1/home/kaydo@thursday    Fri Aug  3 15:19 2012
system1/home/glori@today       Fri Aug  3 15:24 2012
system1/home/hsolo@today       Fri Aug  3 15:24 2012
```

# Disk Space Accounting for ZFS Snapshots

When you create a snapshot, its disk space is initially shared between the snapshot and the file system, and possibly with previous snapshots. As the file system changes, disk space that was previously shared becomes unique to the snapshot, and thus is counted in the snapshot's `used` property. Additionally, deleting snapshots can increase the amount of disk space unique to (and thus *used* by) other snapshots.

A snapshot's space `referenced` property value is the same as the file system's value was when the snapshot was created.

You can identify additional information about how the values of the `used` property are consumed. New read-only file system properties describe disk space usage for clones, file systems, and volumes. For example:

```
$ zfs list -o space -r rpool
NAME                     AVAIL   USED  USEDSNAP  USEDDS  USEDREFRESERV  USEDCHILD
rpool                      124G  9.57G         0    302K              0      9.57G
rpool/ROOT                 124G  3.38G         0     31K              0      3.38G
rpool/ROOT/solaris         124G  20.5K         0       0              0      20.5K
rpool/ROOT/solaris/var     124G  20.5K         0   20.5K              0          0
rpool/ROOT/solaris-1       124G  3.38G     66.3M   3.14G              0       184M
rpool/ROOT/solaris-1/var   124G   184M     49.9M    134M              0          0
rpool/VARSHARE             124G  39.5K         0   39.5K              0          0
rpool/dump                 124G  4.12G         0   4.00G           129M          0
rpool/export               124G    63K         0     32K              0        31K
rpool/export/home          124G    31K         0     31K              0          0
rpool/swap                 124G  2.06G         0   2.00G           64.7M         0
```

For a description of these properties, see the `used` properties in the `zfs`(8) man page.

# Rolling Back a ZFS Snapshot

You can to discard all changes made to a file system since a specific snapshot was created by using the `zfs rollback` command. The file system reverts to its state at the time the snapshot was taken. By default, the command cannot roll back to a snapshot other than the most recent snapshot.

To roll back to an earlier snapshot, you must destroy all intermediate snapshots by specifying the `-r` option.

If clones of any intermediate snapshots exist, use the `-R` option to destroy the clones as well.

> **Note:**
>
> The file system that you want to roll back must be unmounted and remounted, if it is currently mounted. If the file system cannot be unmounted, the rollback fails. Use the `-f` option to force the file system to be unmounted, if necessary.

In the following example, the `system1/home/kaydo` file system is rolled back to the `tuesday` snapshot.

```
$ zfs rollback system1/home/kaydo@tuesday
cannot rollback to 'system1/home/kaydo@tuesday': more recent snapshots exist
use '-r' to force deletion of the following snapshots:
system1/home/kaydo@wednesday
system1/home/kaydo@thursday
$ zfs rollback -r system1/home/kaydo@tuesday
```

In the following example, the `wednesday` and `thursday` snapshots are destroyed because the file system is rolled back to the earlier `tuesday` snapshot.

```
$ zfs list -r -t snapshot -o name,creation system1/home/kaydo
NAME                      CREATION
system1/home/kaydo@tuesday  Fri Aug  3 15:18 2012
```

# Identifying ZFS Snapshot Differences (`zfs diff`)

You can determine ZFS snapshot differences by using the `zfs diff` command.

For example, assume that the following two snapshots are created:

```
$ ls /system1/home/kaydo
fileA
$ zfs snapshot system1/home/cpark@snap1
$ ls /system1/home/kaydo
fileA  fileB
$ zfs snapshot system1/home/cpark@snap2
```

To identify the differences between the two snapshots, you would use syntax similar to the following example:

```
$ zfs diff system1/home/cpark@snap1 system1/home/cpark@snap2
M       /system1/home/kaydo/
+       /system1/home/kaydo/fileB
```

In the output, the `M` indicates that the directory has been modified. The `+` indicates that `fileB` exists in the later snapshot.

The `R` in the following output indicates that a file in a snapshot has been renamed.

```
$ mv /system1/kaydo/fileB /system1/kaydo/fileC
$ zfs snapshot system1/kaydo@snap2
$ zfs diff system1/kaydo@snap1 system1/kaydo@snap2
M       /system1/kaydo/
R       /system1/kaydo/fileB -> /system1/kaydo/fileC
```

The following table summarizes the file or directory changes that are identified by the `zfs diff` command.

| File or Directory Change | Identifier |
|---|---|
| File or directory has been modified or file or directory link has changed | `M` |
| File or directory is present in the older snapshot but not in the more recent snapshot | `--` |
| File or directory is present in the more recent snapshot but not in the older snapshot | `+` |
| File or directory has been renamed | `R` |

For more information, see the `zfs`(8) man page.

If you compare different snapshots by using the`zfs diff` command, the high level differences are displayed such as a new file system or directory. For example, the `sales` file system has 2 descendant file systems, `data` and `logs` with files within each descendant file system.

```
$ zfs list -r sales
NAME         USED  AVAIL  REFER  MOUNTPOINT
sales       1.75M  66.9G    33K  /sales
sales/data   806K  66.9G   806K  /sales/data
sales/logs   806K  66.9G   806K  /sales/logs
```

The high-level differences can be displayed between `sales@snap1` and `sales@snap2`, where the primary difference is addition of the `sales/logs` file system.

```
$ zfs diff sales@snap1 sales@snap2
M       /sales/
+       /sales/logs
```

You can recursively identify snapshot differences including file names by using syntax similar to the following:

```
$ zfs diff -r -E sales@snap1
D       /sales/ (sales)
+       /sales/data
D       /sales/data/    (sales/data)
+       /sales/data/dfile.1
+       /sales/data/dfile.2
+       /sales/data/dfile.3
$ zfs diff -r -E sales@snap2
D       /sales/ (sales)
+       /sales/data
+       /sales/logs
D       /sales/logs/    (sales/logs)
+       /sales/logs/lfile.1
```

```
+       /sales/logs/lfile.2
+       /sales/logs/lfile.3
D       /sales/data/    (sales/data)
+       /sales/data/dfile.1
+       /sales/data/dfile.2
+       /sales/data/dfile.3
```

In the output, the lines that begin with `D` and end with (*name*) indicate a file system (dataset) and mount point.

# Overview of ZFS Clones

A *clone* is a writable volume or file system whose initial contents are the same as the dataset from which it was created. As with snapshots, creating a clone is nearly instantaneous and initially consumes no additional disk space. In addition, you can snapshot a clone.

Clones do not inherit the properties of the dataset from which they were created. Use the `zfs get` and `zfs set` commands to view and change the properties of a cloned dataset. For more information, see Setting ZFS Properties.

Because a clone initially shares all its disk space with the original snapshot, its `used` property value is initially zero. As changes are made to the clone, it uses more disk space. The `used` property of the original snapshot does not include the disk space consumed by the clone.

This section covers the following topics:

- Creating a ZFS Clone
- Destroying a ZFS Clone
- Displaying and Accessing ZFS Clones
- Replacing a ZFS File System With a ZFS Clone

## Creating a ZFS Clone

To create a clone, use the `zfs clone` command, specifying the snapshot or dataset from which to create the clone and the name of the new file system or volume, which can be located anywhere in the ZFS hierarchy. The new dataset is the same type (for example, file system or volume) as the snapshot from which the clone was created. You cannot create a clone of a file system in a pool that is different from where the original file system snapshot resides.

The following example creates a new clone named `system1/home/megra/bug123` with the same initial contents as the snapshot `system1/ws/gate@yesterday`.

```
$ zfs snapshot system1/ws/gate@yesterday
$ zfs clone system1/ws/gate@yesterday system1/home/megra/bug123
```

The following example creates a cloned workspace from the `projects/newproject@today` snapshot for a temporary user as `projects/teamA/tempuser`. Properties then are set on the cloned workspace.

```
$ zfs snapshot projects/newproject@today
$ zfs clone projects/newproject@today projects/teamA/tempuser
$ zfs set share.nfs=on projects/teamA/tempuser
$ zfs set quota=5G projects/teamA/tempuser
```

## Destroying a ZFS Clone

You destroy ZFS clones by using the `zfs destroy` command. For example:

```
$ zfs destroy system1/home/megra/bug123
```

## Displaying and Accessing ZFS Clones

By setting a clone's `mountpoint` property to `clonedir`, you can access the clone in the *mountpoint* `/.zfs/clone` directory that is located in the dataset of which this is a clone. This dataset is called the head dataset.

When you set a clone's `mountpoint` property to `clonedir`, ZFS uses the final part of its dataset name as the clone subdirectory to add to `.zfs/clone`. Thus, ensure that each clone for which you intend to use `clonedir` has a unique name after the final slash for a given head dataset.

In this example, the head dataset is `tank/ds/subds`. Create a clone of the `tank/ds/subds@march` snapshot called `tank/march` and mount it on `/tank/ds/subds`. When you set its `mountpoint` property to `clonedir`, you can access the clone from the `/tank/ds/subds/.zfs/clone/march` directory.

To determine whether a file system is a clone, use the `zfs` command to verify that the value of the `origin` property is non-NULL.

To share a clone that has `mountpoint=clonedir` set, ensure that it is shared from the top-level directory that houses the `.zfs/clone` directory. For example, a file system mounted on `/a` only permits access to its clonedir clones if `/a` is shared and not a subdirectory of `/a`, so the clonedir clones are available in `/a/.zfs/clone`.

When you set a clone's `mountpoint` property to `clonedir`, ZFS does the following:

- Disables any existing shares of that clone.
- Adds the clone directory to its head dataset's `.zfs/clone` directory, such as `tank/ds/subds/.zfs/clone/march`.

You can mount clones in `.zfs/clone` in the following ways:

- The `tank/ds/subds/march` clone is mounted at the `tank/ds/subds` mount point, which is `tank/ds/subds/.zfs/clone/march`.

  Create a clone that sets its `mountpoint` property to `clonedir`.

  ```
  # zfs clone -o mountpoint=clonedir snapshot-name
            clone-name
  ```

  The following command creates a clone of the `tank/ds/subds@snap` snapshot called `tank/ds/subds/march`:

  ```
  # zfs clone -o mountpoint=clonedir tank/ds/subds@march tank/ds/subds/march
  ```

  Assuming that the mount point of `tank/ds/subds` is `/tank/ds/subds`, the `tank/ds/subds/march` clone is mounted on demand at `/tank/ds/subds/.zfs/clone/march`.
- Set an existing clone's `mountpoint` property to `clonedir`.

```
# zfs set -o mountpoint=clonedir clone-name
```

The following command sets the `mountpoint` property to `clonedir` for the existing `tank/ds/subds/march` clone:

```
# zfs set -o mountpoint=clonedir tank/ds/subds/march
```

- Use the `mkdir` command to create a directory for the clone in `.zfs/clone` directory.

  Note that you can use the `mkdir` and `rmdir` commands to create and destroy snapshots and clones, respectively.

  The `mkdir` command creates a snapshot of the head dataset and then clones it.

  ```
  # mkdir .zfs/clone/clone-name
  ```

  For example, with `tank/ds/subds` as the head dataset, the following command does the following:

  – Creates a snapshot called `tank/ds/subds@march` if it does not exist

  – Clones the snapshot as a dataset called `tank/ds/subds/march`

  The resulting mount path is `/tank/ds/subds/.zfs/clone/march` when the mount point of `tank/ds/subds` is the default `/tank/ds/subds`. Note that you can specify any mount point for the mount path.

  ```
  # mkdir .zfs/clone/march
  ```

  As with the `zfs destroy` command, the `rmdir` command does not destroy the origin snapshot.

## Replacing a ZFS File System With a ZFS Clone

To replace an active ZFS file system with a clone of that file system, use the `zfs promote` command. This feature enables you to clone and replace file systems so that the *original* file system becomes the clone of the specified file system. In addition, you can destroy the file system from which the clone was originally created. Without clone promotion, you cannot destroy an original file system of active clones. For more information, see Destroying a ZFS Clone.

In the following example, the `system1/test/productA` file system is cloned and then the clone file system, `system1/test/productAbeta`, becomes the original `system1/test/productA` file system.

```
$ zfs create system1/test
$ zfs create system1/test/productA
$ zfs snapshot system1/test/productA@today
$ zfs clone system1/test/productA@today system1/test/productAbeta
$ zfs list -r system1/test
NAME                          USED  AVAIL  REFER  MOUNTPOINT
system1/test                  104M  66.2G    23K  /system1/test
system1/test/productA         104M  66.2G   104M  /system1/test/productA
system1/test/productA@today      0      -   104M  -
system1/test/productAbeta        0  66.2G   104M  /system1/test/productAbeta
$ zfs promote system1/test/productAbeta
$ zfs list -r system1/test
NAME                            USED  AVAIL  REFER  MOUNTPOINT
```

```
system1/test                     104M  66.2G    24K  /system1/test
system1/test/productA              0  66.2G   104M  /system1/test/productA
system1/test/productAbeta        104M  66.2G   104M  /system1/test/productAbeta
system1/test/productAbeta@today    0      -   104M  -
```

In this `zfs list` output, note that the disk space accounting information for the original `productA` file system has been replaced with the `productAbeta` file system.

You can complete the clone replacement process by renaming the file systems. For example:

```
$ zfs rename system1/test/productA system1/test/productAlegacy
$ zfs rename system1/test/productAbeta system1/test/productA
$ zfs list -r system1/test
```

Optionally, you can remove the legacy file system. For example:

```
$ zfs destroy system1/test/productAlegacy
```

# Saving, Sending, and Receiving ZFS Data

The `zfs send` command creates a stream representation of a snapshot that is written to standard output. By default, a full stream is generated. You can redirect the output to a file or to a different system. The `zfs receive` command creates a snapshot whose contents are specified in the stream that is provided on standard input. If a full stream is received, a new file system is created as well. You can also send ZFS snapshot data and receive ZFS snapshot data and file systems.

In this Oracle Solaris release, the `zfs send` command has been enhanced with `-w compress` option. This option enables a system to perform a raw data transfer. In this type of transfer, data blocks that are compressed are read as is on the source disk and written as is on the target. No decompression-recompression occurs during the operation.

. This system can still receive data transfers from a source that does not have the `zfs send -w compress` option, such as systems running previous Oracle Solaris releases. In this case, the default behavior applies, where the compressed data blocks are first decompressed before they are transferred to the target system. After the transfer is complete, the blocks are then recompressed on the receiving system. For more information, see Sending ZFS Data Using Raw Transfer.

In addition, this release includes the ability to resume transferring ZFS data. In particular, the transfer of large amounts of ZFS data can be interrupted due to network outages or system failure. To prevent having to resend the whole thing again, the `zfs send` and `zfs receive` commands can be run with the `-C` option to resume sending the ZFS data. For more information, see Using Resumable Replication.

This section covers the following topics:

- Saving ZFS Data With Other Backup Products
- Types of ZFS Snapshot Streams
- Sending a ZFS Snapshot
- Receiving a ZFS Snapshot
- Applying Different Property Values to a ZFS Snapshot Stream
- Sending and Receiving Complex ZFS Snapshot Streams
- Sending and Receiving Encrypted ZFS Data
- Remote Replication of ZFS Data

Note the following backup solutions for saving ZFS data:

- **Enterprise backup products** – These products provide the following features:
  - Per-file restoration
  - Backup media verification
  - Media management
- **File system snapshots and rolling back snapshots** – Create a copy of a file system and revert to a previous file system version, if necessary.

  For more information about creating and rolling back to a snapshot, see Overview of ZFS Snapshots.
- **Saving snapshots** – Using the `zfs send` and `zfs receive` commands, you can save incremental changes between snapshots but you cannot restore files individually. You must restore the entire file system snapshot..
- **Remote replication** – Copy a file system from one system to another system. This process is different from a traditional volume management product that might mirror devices across a WAN. No special configuration or hardware is required. Using the `zfs send` and `zfs receive` commands to replicate a ZFS file system enables you to re-create a file system on a storage pool on another system, and specify different levels of configuration for the newly created pool, such as RAID-Z, but with identical file system data.
- **Archive utilities** – Save ZFS data with archive utilities such as `tar`, `cpio`, and `pax` or third-party backup products. Currently, both `tar` and `cpio` translate NFSv4-style ACLs correctly, but `pax` does not.

## Saving ZFS Data With Other Backup Products

In addition to the `zfs send` and `zfs receive` commands, you can also use archive utilities such as the `tar` and `cpio` commands, to save ZFS files. These utilities save and restore ZFS file attributes and ACLs. Check the appropriate options for both the `tar` and `cpio` commands.

## Types of ZFS Snapshot Streams

The `zfs send` command can be used to create a stream of one or more snapshots. Then, you can use the snapshot stream to re-create a ZFS file system or volume by using the `zfs receive` command.

The `zfs send` options used to create the snapshot stream determine the stream format type that is generated.

- Full stream – Consists of all dataset content from the time that the dataset was created up to the specified snapshot.

  The default stream generated by the `zfs send` command is a full stream. It contains one file system or volume, up to and including the specified snapshot. The stream does not contain snapshots other than the snapshot specified in the command.
- Incremental stream – Consists of the differences between one snapshot and another snapshot.

A *stream package* is a stream type that contains one or more full or incremental streams. The types of stream packages are:

- Replication stream package – Consists of the specified dataset and its descendants. It includes all intermediate snapshots. If the origin of a cloned dataset is not a descendant of the snapshot specified on the command line, that origin dataset is not included in the stream package. To receive the stream, the origin dataset must exist in the destination storage pool.

  > **Note:**
  >
  > A self-contained replication stream does not have external dependencies. See the section on self-contained replication streams below.

  Assume that the following list of datasets and their origins were created in the order in which they appear.

```
NAME                    ORIGIN
pool/a                  -
pool/a/1                -
pool/a/1@clone          -
pool/b                  -
pool/b/1                pool/a/1@clone
pool/b/1@clone2         -
pool/b/2                pool/b/1@clone2
pool/b@pre-send         -
pool/b/1@pre-send       -
pool/b/2@pre-send       -
pool/b@send             -
pool/b/1@send           -
pool/b/2@send           -
```

  Suppose you have a replication stream package created with the following syntax:

```
$ zfs send -R pool/b@send ....
```

  This package would consist of the following full and incremental streams:

```
TYPE    SNAPSHOT                INCREMENTAL FROM
full    pool/b@pre-send         -
incr    pool/b@send             pool/b@pre-send
incr    pool/b/1@clone2         pool/a/1@clone
incr    pool/b/1@pre-send       pool/b/1@clone2
incr    pool/b/1@send           pool/b/1@send
incr    pool/b/2@pre-send       pool/b/1@clone2
incr    pool/b/2@send           pool/b/2@pre-send
```

  In the output, the `pool/a/1@clone` snapshot is not included in the replication stream package. Therefore, this replication stream package can only be received in a pool that already has `pool/a/1@clone` snapshot.

- **Self-contained replication stream package** - This type of package is not dependent on any datasets that are not included in the stream package. You create a replication stream package with syntax similar to the following example:

```
$ zfs send -Rc pool/b@send ...
```

  This example package would consist of the following full and incremental streams:

```
TYPE    SNAPSHOT            INCREMENTAL FROM
full    pool/b@pre-send     -
full    pool/b/1@clone2     -
incr    pool/b@send         pool/b@pre-send
```

```
incr    pool/b/1@pre-send    pool/b/1@clone2
incr    pool/b/1@send        pool/b/1@send
incr    pool/b/2@pre-send    pool/b/1@clone2
incr    pool/b/2@send        pool/b/2@pre-send
```

Comparing with the non-self-contained replication stream, notice that this self-contained replication stream has an integrated full stream of the `pool/b/1@clone2` snapshot. This snapshot is an integrated dataset that has clone origin bits merged into it as data; `clone2` is no longer a full clone with a separate origin. This makes it possible to receive the `pool/b/1` snapshot with no external dependencies.

- **Recursive stream package** – Consists of the specified dataset and its descendants. Unlike replication stream packages, intermediate snapshots are not included unless they are the origin of a cloned dataset that is included in the stream. By default, if the origin of a dataset is not a descendant of the snapshot specified in the command, the behavior is similar to replication streams. Note that a self-contained recursive stream does not have external dependencies.

> **Note:**
>
> A self-contained recursive stream does not have external dependencies. See the section on self-contained recursive streams below.

You create a recursive stream package with syntax similar to the following example:

```
$ zfs send -r pool/b@send ...
```

This example package would consist of the following full and incremental streams:

```
TYPE    SNAPSHOT               INCREMENTAL FROM
full    pool/b@send            -
incr    pool/b/1@clone2        pool/a/1@clone
incr    pool/b/1@send          pool/b/1@clone2
incr    pool/b/2@send          pool/b/1@clone2
```

In the output, the `pool/a/1@clone` snapshot is not included in the recursive stream package. Therefore, similar to the replication stream package,this recursive stream package can only be received in a pool that already has `pool/a/1@clone` snapshot. This behavior is similar to the replication stream package scenario described above.

- **Self-contained recursive stream package** - This type of package is not dependent on any datasets that are not included in the stream package. You create a recursive stream package with syntax similar to the following example:

```
$ zfs send -rc pool/b@send ...
```

This example package would consist of the following full and incremental streams:

```
TYPE    SNAPSHOT               INCREMENTAL FROM
full    pool/b@send            -
full    pool/b/1@clone2        -
incr    pool/b/1@send          pool/b/1@clone2
incr    pool/b/2@send          pool/b/1@clone2
```

## Sending a ZFS Snapshot

You can use the `zfs send` command to send a copy of a snapshot stream and receive the snapshot stream in another pool on the same system or in another pool on a different system

that is used to store backup data. For example, to send the snapshot stream on a different pool to the same system, use a command similar to the following example:

```
$ zfs send pool/diant@snap1 | zfs recv spool/ds01
```

> **Tip:**
>
> You can use `zfs recv` as an alias for the `zfs receive` command.

If you are sending the snapshot stream to a different system, pipe the `zfs send` output through the `ssh` command. For example:

```
sys1$ zfs send pool/diant@snap1 | ssh sys2 zfs recv pool/hsolo
```

When you send a full stream, the destination file system must not exist.

If you need to store many copies, consider compressing a ZFS snapshot stream representation with the `gzip` command. For example:

```
$ zfs send pool/fs@snap | gzip > backupfile.gz
```

### Example 8-1 Sending Incremental ZFS Data

You can send incremental data by using the `zfs send -i` option. For example:

```
sys1$ zfs send -i pool/diant@snap1 system1/diant@snap2 | ssh system2 zfs recv \
pool/hsolo
```

The first argument (`snap1`) is the earlier snapshot and the second argument (`snap2`) is the later snapshot. In this case, the `pool/hsolo` file system must already exist for the incremental receive to be successful.

You can specify the incremental *snap1* source as the last component of the snapshot name. You would then have to specify only the name after the `@` sign for *snap1*, which is assumed to be from the same file system as *snap2*. For example:

```
sys1$ zfs send -i snap1 pool/diant@snap2 | ssh system2 zfs recv pool/hsolo
```

This shortcut syntax is equivalent to the incremental syntax.

The following message is displayed if you attempt to generate an incremental stream from a different file system `snapshot1`:

```
cannot send 'pool/fs@name': not an earlier snapshot from the same fs
```

Accessing file information in the original received file system can cause the incremental snapshot receive operation to fail with a message similar to this one:

```
cannot receive incremental stream of pool/diant@snap2 into pool/hsolo:
most recent snapshot of pool/diant@snap2 does not match incremental source
```

Consider setting the `atime` property to `off` if you need to access file information in the original received file system and if you also need to receive incremental snapshots into the received file system.

If you need to store many copies, consider compressing a ZFS snapshot stream representation with the `gzip` command. For example:

```
$ zfs send pool/fs@snap | gzip > backupfile.gz
```

**Example 8-2 Sending ZFS Data Using Raw Transfer**

To send the stream in raw mode, use the `-w compress` option.

The following example shows that the raw transfer stream for a given snapshot is smaller, even though the file system created after receiving the stream is the same as the original. First, create a file system called `pool/compressed-fs` which you fill with data.

```
$ zfs create -o compression=gzip-6 pool/compressed-fs
$ cp /usr/dict/words /pool/compressed-fs/
```

Next, create a snapshot and check the compression ratio. For comparison purposes, create two streams to see the difference in sizes between a regular transfer and a raw transfer, Note that the `rawstream` file is smaller.

```
$ zfs snapshot pool/compressed-fs@snap
$ zfs get compressratio pool/compressed-fs@snap
NAME                         PROPERTY       VALUE  SOURCE
pool/compressed-fs@snap  compressratio  2.80x  -
$ zfs send pool/compressed-fs@snap > /tmp/stream
$ zfs send -w compress pool/compressed-fs@snap > /tmp/rawstream
$ ls -lh /tmp/*stream
-rw-r--r--   1 root     root        100K Dec 23 18:23 /tmp/rawstream
-rw-r--r--   1 root     root        304K Dec 23 18:23 /tmp/stream
```

Next, receive the raw transfer stream on its new location. Then to verify that the content is identical, compare the new file system to the original.

```
$ zfs receive pool/rawrecv </tmp/rawstream
$ diff -r /pool/compressed-fs/ /pool/rawrecv/
$
```

**Example 8-3 Sending ZFS Data From a Oracle Solaris 11.4.0 Dataset**

The ability to use per record checksums in the output data stream is enabled by default. To transfer data to older systems, you must disable this feature using the `nocheck` argument.

```
$ zfs send -s nocheck pool/diant@snap1 | zfs recv pool/ds01
```

# Using Resumable Replication

If the transfer of data using `zfs receive` is interrupted, you can restart the process. For instance, if you started the transfer with this command.

```
system1$ zfs send pool/diant@snap1 | ssh system2 zfs recv pool/hsolo
```

If the transfer is interrupted, you will have an incomplete dataset. You can resume the transfer using this series of commands:

```
system1$ ssh system2 zfs receive -C pool/hsolo | zfs send -C pool/diant@snap1 | \
ssh system2 zfs receive pool/hsolo
```

To see which datasets are incomplete use the `zfs list -I` command, see Listing Incomplete ZFS Datasets.

# Receiving a ZFS Snapshot

Keep the following key points in mind when you receive a file system snapshot:

- Both the snapshot and the file system are received.

- The file system and all descendant file systems are unmounted.
- The file systems are inaccessible while they are being received.
- A file system with the same name as the source file system to be received must not exist on the target system. If the file system name exists on the target system, rename the file system.

For example:

```
$ zfs send system1/gozer@0830 > /bkups/gozer.083006
$ zfs receive system1/gozer2@today < /bkups/gozer.083006
$ zfs rename system1/gozer system1/gozer.old
$ zfs rename system1/gozer2 system1/gozer
```

If you make a change to the destination file system and you want to perform another incremental send of a snapshot, you must first roll back the receiving file system.

Consider the following example. First, make a change to the file system as follows:

```
sys2$ rm newsys/hsolo/file.1
```

Then, perform an incremental send of `system1/diant@snap3`. Note that either you must first roll back the receiving file system to receive the new incremental snapshot or eliminate the rollback step by using the `-F` option. For example:

```
sys1$ zfs send -i system1/diant@snap2 system1/diant@snap3 | ssh sys2 zfs recv \
-F newsys/hsolo
```

When you receive an incremental snapshot, the destination file system must already exist.

If you make changes to the file system and you do not roll back the receiving file system to receive the new incremental snapshot or you use the `-F` option, a message similar to the following example is displayed:

```
sys1$ zfs send -i system1/diant@snap4 system1/diant@snap5 | ssh sys2 zfs recv \
newsys/hsolo
cannot receive: destination has been modified since most recent snapshot
```

The following checks are performed before the `-F` option is successful:

- If the most recent snapshot does not match the incremental source, neither the rollback nor the receive is completed, and an error message is returned.
- If you accidentally provide the name of different file system that does not match the incremental source specified in the `zfs receive` command, neither the rollback nor the receive is completed, and the following error message is returned:

  ```
  cannot send 'pool/fs@name': not an earlier snapshot from the same fs
  ```

# Applying Different Property Values to a ZFS Snapshot Stream

You can send a ZFS snapshot stream with a certain file system property value, and then either specify a different local property value when the snapshot stream is received or specify that the original property value be used when the snapshot stream is received to re-create the original file system. In addition, you can disable a file system property when the snapshot stream is received.

- To revert a local property value to the received value, if any, use the `zfs inherit -S` command. If a property does not have a received value, the behavior of the `-S` option is the same as if you did not include the option. If the property does have a received value,

the `zfs inherit` command masks the received value with the inherited value until issuing a `zfs inherit -S` command reverts it to the received value.

- You can determine the columns displayed by the `zfs get`. Use the `-o` option to include the new non-default `RECEIVED` column. Use the `-o all` option to include all columns, including `RECEIVED`.
- To include properties in the send stream without the `-R` option, use the `-p` option.
- To use the last element of the sent snapshot name to determine the new snapshot name, use the `-e` option.

  The following example sends the `poolA/bee/cee@1` snapshot to the `poolD/eee` file system and uses only the last element (`cee@1`) of the snapshot name to create the received file system and snapshot.

```
$ zfs list -rt all poolA
NAME              USED  AVAIL  REFER  MOUNTPOINT
poolA             134K   134G    23K  /poolA
poolA/bee          44K   134G    23K  /poolA/bee
poolA/bee/cee      21K   134G    21K  /poolA/bee/cee
poolA/bee/cee@1      0      -    21K  -
$ zfs send -R poolA/bee/cee@1 | zfs receive -e poolD/eee
$ zfs list -rt all poolD
NAME              USED  AVAIL  REFER  MOUNTPOINT
poolD             134K   134G    23K  /poolD
poolD/eee          44K   134G    23K  /poolD/eee
poolD/eee/cee      21K   134G    21K  /poolD/eee/cee
poolD/eee/cee@1      0      -    21K  -
```

## Retaining Original Property Values

In some cases, file system properties in a send stream might not apply to the receiving file system or local file system properties, such as the `mountpoint` property value, might interfere with a restore.

For example, suppose that the `system1/data` file system has the `compression` property disabled. A snapshot of the `system1/data` file system is sent with properties (`-p` option) to a backup pool and is received with the `compression` property enabled.

```
$ zfs get compression system1/data
NAME          PROPERTY     VALUE     SOURCE
system1/data  compression  off       default
$ zfs snapshot system1/data@snap1
$ zfs send -p system1/data@snap1 | zfs recv -o compression=on -d bpool
$ zfs get -o all compression bpool/data
NAME        PROPERTY     VALUE     RECEIVED  SOURCE
bpool/data  compression  on        off       local
```

In the example, the `compression` property is enabled when the snapshot is received into `bpool`. So, for `bpool/data`, the `compression` value is `on`.

If this snapshot stream is sent to a new pool, `restorepool`, for recovery purposes, you might want to keep all the original snapshot properties. In this case, you would use the `zfs send -b` command to restore the original snapshot properties. For example:

```
$ zfs send -b bpool/data@snap1 | zfs recv -d restorepool
$ zfs get -o all compression restorepool/data
NAME              PROPERTY     VALUE     RECEIVED  SOURCE
restorepool/data  compression  off       off       received
```

In the example, the compression value is `off`, which represents the snapshot compression value from the original `system1/data` file system.

## Disabling Original Property Values

If you have a local file system property value in a snapshot stream and you want to disable the property when it is received, use the `zfs receive -x` command. For example, the following command sends a recursive snapshot stream of home directory file systems with all file system properties reserved to a backup pool but without the quota property values:

```
$ zfs send -R system1/home@snap1 | zfs recv -x quota bpool/home
$ zfs get -r quota bpool/home
NAME                     PROPERTY  VALUE  SOURCE
bpool/home               quota     none   local
bpool/home@snap1         quota     -      -
bpool/home/glori         quota     none   default
bpool/home/glori@snap1   quota     -      -
bpool/home/hsolo         quota     none   default
bpool/home/hsolo@snap1   quota     -      -
```

If the recursive snapshot was not received with the `-x` option, the quota property would be set in the received file systems.

```
$ zfs send -R system1/home@snap1 | zfs recv bpool/home
$ zfs get -r quota bpool/home
NAME                     PROPERTY  VALUE  SOURCE
bpool/home               quota     none   received
bpool/home@snap1         quota     -      -
bpool/home/glori         quota     10G    received
bpool/home/glori@snap1   quota     -      -
bpool/home/hsolo         quota     10G    received
bpool/home/hsolo@snap1   quota     -      -
```

# Sending and Receiving Complex ZFS Snapshot Streams

This section describes how to use the `-I` and `-R` options with the `zfs send` command to send and receive more complex snapshot streams.

Keep the following points in mind when sending and receiving complex ZFS snapshot streams:

- To send all incremental streams from one snapshot to a cumulative snapshot, use the `-I` option. You can also use this option to send an incremental stream from the original snapshot to create a clone. The original snapshot must already exist on the receiving side to accept the incremental stream.
- To send a replication stream of all descendant file systems, use the `-R` option. When the replication stream is received, all properties, snapshots, descendant file systems, and clones are preserved.
- Using the `zfs send -r` command or the `zfs send -R` command to send package streams without the `-c` option will omit the `origin` of clones in some circumstances. For more information, see Types of ZFS Snapshot Streams.
- Use both options to send an incremental replication stream.
  - Changes to properties are preserved, as are snapshot and file system `rename` and `destroy` operations.

  - If the `-F` option is not specified when receiving the replication stream, dataset `destroy` operations are ignored. Thus, if necessary, you can undo the receive operation and restore the file system to its previous state.
  - When sending incremental streams, if `-I` is used, all snapshots between `snapA` and `snapD` are sent. If `-i` is used, only `snapD` (for all descendants) snapshots are sent.
- To receive any of these types of `zfs send` streams, the receiving system must be running a software version capable of sending them. The stream version is incremented.

**Example 8-4 Sending and Receiving Complex ZFS Snapshot Streams**

You can combine A group of incremental snapshots into one snapshot by using the `-I` option. For example:

```
$ zfs send -I pool/fs@snapA pool/fs@snapD > /snaps/fs@all-I
```

You would then remove the incremental `snapB`, `snapC`, and `snapD` snapshots.

```
$ zfs destroy pool/fs@snapB
$ zfs destroy pool/fs@snapC
$ zfs destroy pool/fs@snapD
```

To receive the combined snapshot, you would use the following command.

```
$ zfs receive -d -F pool/fs < /snaps/fs@all-I
$ zfs list
NAME                      USED  AVAIL  REFER  MOUNTPOINT
pool                      428K  16.5G    20K  /pool
pool/fs                    71K  16.5G    21K  /pool/fs
pool/fs@snapA              16K      -  18.5K  -
pool/fs@snapB              17K      -    20K  -
pool/fs@snapC              17K      -  20.5K  -
pool/fs@snapD                0      -    21K  -
```

You can also use the `-I` command to combine a snapshot and a clone snapshot to create a combined dataset. For example:

```
$ zfs create pool/fs
$ zfs snapshot pool/fs@snap1
$ zfs clone pool/fs@snap1 pool/clone
$ zfs snapshot pool/clone@snapA
$ zfs send -I pool/fs@snap1 pool/clone@snapA > /snaps/fsclonesnap-I
$ zfs destroy pool/clone@snapA
$ zfs destroy pool/clone
$ zfs receive -F pool/clone < /snaps/fsclonesnap-I
```

To replicate a ZFS file system and all descendant file systems up to the named snapshot, use the `-R` option. When this stream is received, all properties, snapshots, descendant file systems, and clones are preserved.

The following example creates snapshots for user file systems. One replication stream is created for all user snapshots. Next, the original file systems and snapshots are destroyed and then recovered.

```
$ zfs snapshot -r users@today
$ zfs list
NAME                 USED  AVAIL  REFER  MOUNTPOINT
users                187K  33.2G    22K  /users
users@today             0      -    22K  -
users/user1           18K  33.2G    18K  /users/user1
users/user1@today       0      -    18K  -
users/user2           18K  33.2G    18K  /users/user2
```

```
users/user2@today      0      -    18K  -
users/user3           18K  33.2G    18K  /users/user3
users/user3@today      0      -    18K  -
$ zfs send -R users@today > /snaps/users-R
$ zfs destroy -r users
$ zfs receive -F -d users < /snaps/users-R
$ zfs list
NAME                 USED  AVAIL  REFER  MOUNTPOINT
users                196K  33.2G    22K  /users
users@today             0      -    22K  -
users/user1           18K  33.2G    18K  /users/user1
users/user1@today       0      -    18K  -
users/user2           18K  33.2G    18K  /users/user2
users/user2@today       0      -    18K  -
users/user3           18K  33.2G    18K  /users/user3
users/user3@today       0      -    18K  -
```

The following example uses the `-R` command to replicate the `users` file system and its descendants, and to send the replicated stream to another pool, `users2`.

```
$ zfs create users2 mirror c0t1d0 c1t1d0
$ zfs receive -F -d users2 < /snaps/users-R
$ zfs list
NAME                  USED  AVAIL  REFER  MOUNTPOINT
users                 224K  33.2G    22K  /users
users@today              0      -    22K  -
users/user1            33K  33.2G    18K  /users/user1
users/user1@today      15K      -    18K  -
users/user2            18K  33.2G    18K  /users/user2
users/user2@today        0      -    18K  -
users/user3            18K  33.2G    18K  /users/user3
users/user3@today        0      -    18K  -
users2                188K  16.5G    22K  /users2
users2@today             0      -    22K  -
users2/user1           18K  16.5G    18K  /users2/user1
users2/user1@today       0      -    18K  -
users2/user2           18K  16.5G    18K  /users2/user2
users2/user2@today       0      -    18K  -
users2/user3           18K  16.5G    18K  /users2/user3
users2/user3@today       0      -    18K  -
```

# Sending and Receiving Encrypted ZFS Data

By default, the `zfs send` command transfers encrypted data blocks by first decrypting the data on the source and then re-encrypting the data on the target. Note that the data blocks are re-encrypted only if encryption is enabled for the target.

The Oracle Solaris 11.4 SRU 57 release provides a way to avoid the decryption and re-encryption steps by using the `zfs send -w crypto` command. This command transfers encrypted data blocks in `rawcrypto` mode, which sends encrypted data blocks as-is from the source to the target.

Using the `-w crypto` option implicitly specifies the `-p` option. The `-w crypto` option is mutually exclusive with the `-D` option.

When you do not specify the `-w` option, the default value is `-w compress`. The default value for NDMP is `-w none`.

The `rawcrypto` mode also provides additional security by ensuring that the destruction of a single key on an external key management server (OKM or KMIP) is sufficient to make the encrypted data inaccessible.

A target can receive a `rawcrypto` stream successfully only if the `keysource` property value is identical on both the source and target systems. For example, if you use the `file:///` method to specify the location, ensure that the file contents and its location are the same on the source and target systems.

Only a target that uses at least ZFS Pool Version 50 (Raw Crypto Replication) can receive a send stream that you create by using the `zfs send -w crypto` command.

When a target receives a snapshot by using `rawcrypto` mode, subsequent updates to the same target dataset that contains that snapshot must use `rawcrypto` mode, as well. Conversely, when the target does not use `rawcrypto` mode to receive a snapshot, subsequent updates to the same target dataset that contains that snapshot must not use `rawcrypto` mode either.

> **Note:**
>
> If you specify the `-w crypto` option to send an unencrypted snapshot, the `zfs send` command does not use `rawcrypto` mode.

The following example commands show how to transfer the `tank/encrypted-fs@snap1` snapshot to the `dst/fs1` dataset on the `target1` system in `rawcrypto` mode:

```
# zfs send -w crypto tank/encrypted-fs@snap1 | ssh target1 zfs recv -f dst/fs1
```

The following example commands show that the `zfs send -w crypto` command can send a snapshot that has more than one encryption key:

```
# zfs key -K tank/encrypted-fs
# zfs snapshot tank/encrypted-fs@snap2
# zfs send -w crypto tank/encrypted-fs@snap2 | ssh target2 zfs recv -f dst/fs2
```

## Remote Replication of ZFS Data

You can use the `zfs send` and `zfs recv` commands to remotely copy a snapshot stream representation from one system to another system. For example:

```
$ zfs send system1/kaydo@today | ssh newsys zfs recv sandbox/restfs@today
```

This command sends the `system1/kaydo@today` snapshot data and receives it into the `sandbox/restfs` file system. The command also creates a `restfs@today` snapshot on the `newsys` system. In this example, the user has been configured to use `ssh` on the remote system.

# Monitoring ZFS Pool Operations

When you issue ZFS commands that initiate background tasks to run on the data such as sending, receiving, scrubbing, or resilvering data, you can monitor the status and progress of these tasks in real time. You can specify the frequency rate in which information is displayed. You can also determine for how long the monitoring should run.

To monitor pool operations, you use the `zpool monitor` command. Depending on which options you use, the command provides the following information about the task. The information is provided for each individual pool.

- Start time.
- Current amount of data.
- Timestamp, if appropriate on a per feature basis.
- Amount of data at start of the task, if appropriate.

You can display information about tasks on an individual pool or on all existing pools on the system.

Use the `zpool monitor` command as follows:

`zpool monitor -t` *provider* `[-T d|u]` `[`*pool*`]` `[`*interval* `[`*count*`]]`

**`-t` *provider***
Specifies one of the following providers about which the task information is displayed. For provider, you can specify one of the following:

- `send`
- `receive` or `recv`
- `scrub`
- `resilver`

> **Note:**
>
> For an updated list of providers, type the `zpool help monitor` command.

**`-T` d|u**
Specifies the time stamp and its display format. To display in standard date format, specify `d`. To display a printed representation of the internal representation of time, specify `u`. For more information about these display formats, see the `date`(1) and the `time`(2) man pages.

***interval***
Rate, in seconds, at which the displayed information is updated.

***count***
Number of times the command displays task-related information within the specified interval. If *count* is specified, then the command updates the information for as many times as specified by `count` before exiting. If *count* is not specified, then the information is updated continuously until you press Ctrl-C.

> **Note:**
>
> You can also customize the information to display. With the `-o` option, you can filter the display fields to be included in the command output. With the `-p` option, you can display information in machine-parsable format. For more information, see the `zpool`(8) man page.

The command output arranges the information according to specific fields:

**DONE**
Amount of data that has been processed so far since the `zpool monitor` command was issued.

**OTHER**
Additional information depending on the specified provider, such as the current item being processed, or the current state of the task.

**PCTDONE**
Percentage of data that has been processed.

**POOL**
Pool from which the information is retrieved.

**PROVIDER**
Task that is providing the information.

**SPEED**
Units per second, usually bytes but dependent on the unit that the provider uses.

**STRTTIME**
Time the provider started on the displayed task.

**TAG**
Distinguishes whole operations. The TAG value is unique at any one time but values can reused in subsequent operations. For example, two simultaneous send operations would have different TAG values even if both tasks operate on the same dataset.

**TIMELEFT**
Relative time that a specific task will be completed.

**TIMESTMP**
Time the monitored data snapshot is taken.

**TOTAL**
Estimate of total amount of data to be processed.

### Example 8-5 Monitoring a ZFS Snapshot Stream Representation

The `zfs send` command creates a stream representation of a snapshot. The following example shows how to obtain information about this task. The information would be updated two times in a 5-second interval.

```
$ zpool monitor -t send 5 2
POOL       PROVIDER PCTDONE  TOTAL   SPEED   TIMELEFT   OTHER
poolA      send     41.7     10.0G   5.93M   16m49s     poolA/fs:1/team3@all
poolB      send     53.9     10.0G   7.71M   10m13s     poolB/fs1/team3@all
poolC      send     97.9     10.0G   14.4M      14s     poolC/fs1/team1@all
poolA      send     43.5     10.0G   6.17M   15m40s     poolA/fs:1/team3@all
poolB      send     55.8     10.0G   7.95M    9m30s     poolB/fs1/team3@all
poolC      send     99.2     10.0G   14.5M       5s     poolC/fs1/team1@all
```

### Example 8-6 Monitoring the Reception of a Stream

This example shows how to monitor the status and progress of a receive operation. Without a designated count, the information is continuously updated every 5 seconds. The monitoring ends when the administrator presses Ctrl-C.

```
$ zpool monitor -t recv 5
pool           provider  pctdone  total speed timeleft   other
```

```
poolA          receive    34.0    12.0G 6.01M 22m31s     poolA/backup_all/fs2
poolA          receive    68.0    6.01G 6.01M 5m28s      poolA/backup_fs:1
poolB          receive    20.6    10.0G 3.04M 44m39s     poolB/backup_all/fs2
poolB          receive   100.0    6.01G 9.48M 1s         poolB/backup_fs1
poolB          receive    16.7    12.0G 4.16M 41m04s     poolB/pA-bkup/fs2
poolC          receive    26.2    10.0G 3.98M 31m41s     poolC/backup_all/fs2
^C
```

**Example 8-7 Monitoring a Resilvering Operation**

This example shows how to check the status of a resilvering operation on all the three ZFS pools on the system.

```
$ zpool monitor -t resilver 5 4
pool       provider  pctdone  total  speed  timeleft   other
poolA      resilver   10.7    12.0G  37.7M  4m50s      (2/2)
poolB      resilver    7.1    10.0G  31.5M  5m02s      (2/2)
poolC      resilver    1.8    10.0G  42.9M  3m54s      (2/2)
poolA      resilver   13.9    12.0G  38.0M  4m38s      (2/2)
poolB      resilver    9.0    10.0G  30.4M  5m07s      (2/2)
poolC      resilver    5.3    10.0G  41.7M  3m52s      (2/2)
poolA      resilver   14.7    12.0G  36.1M  4m50s      (2/2)
poolB      resilver   10.8    10.0G  29.2M  5m12s      (2/2)
poolC      resilver    7.2    10.0G  41.0M  3m51s      (2/2)
poolA      resilver   14.7    12.0G  32.8M  5m19s      (2/2)
poolB      resilver   10.8    10.0G  29.6M  5m08s      (2/2)
poolC      resilver    7.2    10.0G  40.7M  3m53s      (2/2)
```

**Example 8-8 Monitoring a Scrubbing Operation**

This example shows how to monitor the progress of a scrubbing operation on `poolB`.

```
$ zpool monitor -t scrub 5 poolB
pool        provider  pctdone  total  speed  timeleft
poolB       scrub      16.3    14.0G  35.3M   5m39s
poolB       scrub      16.4    14.0G  33.2M   6m00s
poolB       scrub      16.5    14.0G  31.1M   6m25s
poolB       scrub      16.5    14.0G  29.3M   6m48s
^C
```

# Copying ZFS Files

You can quickly copy large files using the `cp -z` command. The `-z` option copies the metadata associated with each record, rather than copying the metadata and all of the data. For files with record sizes of 4K or more, this method can be much faster than using the standard `cp` command. It is also very useful if you need to make many copies of one large file, like an OS image. See the `reflink`(3C) man page for more information.

9

# Oracle Solaris ZFS Delegated Administration

This chapter describes how to use delegated administration to allow nonprivileged users to perform ZFS administration tasks.

The following sections are provided in this chapter:

- Overview of ZFS Delegated Administration.
- Delegating ZFS Permissions.
- Displaying ZFS Delegated Permissions Examples.
- Delegating ZFS Permissions Examples.
- Removing ZFS Delegated Permissions Examples.

## Overview of ZFS Delegated Administration

ZFS delegated administration enables you to distribute refined permissions to specific users, groups, or everyone. Two types of delegated permissions are supported:

- Individual permissions can be explicitly delegated such as `create`, `destroy`, `mount`, `snapshot`, and so on.
- Groups of permissions called *permission sets* can be defined. A permission set can later be updated, and all of the consumers of the set automatically get the change. Permission sets begin with the `@` symbol and are limited to 64 characters in length. After the `@` symbol, the remaining characters in the set name have the same restrictions as normal ZFS file system names.

ZFS delegated administration provides features similar to the RBAC security model. ZFS delegation provides the following advantages for administering ZFS storage pools and file systems:

- Permissions follow the ZFS storage pool whenever a pool is migrated.
- Provides dynamic inheritance where you can control how the permissions propagate through the file systems.
- Can be configured so that only the creator of a file system can destroy the file system.
- You can delegate permissions to specific file systems. Newly created file systems can automatically pick up permissions.
- Provides simple NFS administration. For example, a user with explicit permissions can create a snapshot over NFS in the appropriate `.zfs/snapshot` directory.

Consider using delegated administration for distributing ZFS tasks. For information about using RBAC to manage general Oracle Solaris administration tasks, see Chapter 1, About Using Rights to Control Users and Processes in *Securing Users and Processes in Oracle Solaris 11.4* .

By default, the `delegation` property is enabled.

You control the delegated administration features by using a pool's `delegation` property. For example:

```
$ zpool get delegation users
NAME   PROPERTY    VALUE       SOURCE
users  delegation  on          default
$ zpool set delegation=off users
$ zpool get delegation users
NAME   PROPERTY    VALUE       SOURCE
users  delegation  off         local
```

# Delegating ZFS Permissions

You can use the `zfs allow` command to delegate permissions on ZFS file systems to non-root users in the following ways:

- Individual permissions can be delegated to a user, group, or everyone.
- Groups of individual permissions can be delegated as a *permission set* to a user, group, or everyone.
- Permissions can be delegated either locally to the current file system only or to all descendants of the current file system.

The following table describes the operations that can be delegated and any dependent permissions that are required to perform the delegated operations.

| Permission (Subcommand) | Description | Dependencies |
|---|---|---|
| `allow` | The permission to grant permissions that you have to another user. | Must also have the permission that is being allowed. |
| `clone` | The permission to clone any of the dataset's snapshots. | Must also have the `create` permission and the `mount` permission in the original file system. |
| `create` | The permission to create descendant datasets. | Must also have the `mount` permission. |
| `destroy` | The permission to destroy a dataset. | Must also have the `mount` permission. |
| `diff` | The permission to identify paths within a dataset. | Non-root users need this permission to use the `zfs diff` command. |
| `hold` | The permission to hold a snapshot. | |
| `mount` | The permission to mount and unmount a file system, and create and destroy volume device links. | |
| `promote` | The permission to promote a clone to a dataset. | Must also have the `mount` permission and the `promote` permission in the original file system. |
| `receive` | The permission to create descendant file systems with the `zfs receive` command. | Must also have the `mount` permission and the `create` permission. |
| `release` | The permission to release a snapshot hold, which might destroy the snapshot. | |
| `rename` | The permission to rename a dataset. | Must also have the `create` permission and the `mount` permission in the new parent. |
| `rollback` | The permission to roll back a snapshot. | |

| Permission (Subcommand) | Description | Dependencies |
|---|---|---|
| `send` | The permission to send a snapshot stream. | |
| `share` | The permission to share and unshare a file system. | Must have both `share` and `share.nfs` to create an NFS share.<br>Must have both `share` and `share.smb` to create an SMB share. |
| `snapshot` | The permission to create a snapshot of a dataset. | |

You can delegate the following set of permissions but a permission might be limited to access, read, or change permission:

- `groupquota`
- `groupused`
- `key`
- `keychange`
- `userprop`
- `userquota`
- `userused`

In addition, you can delegate administration of the following ZFS properties to non-root users:

- `aclinherit`
- `aclmode`
- `atime`
- `canmount`
- `casesensitivity`
- `checksum`
- `compression`
- `copies`
- `dedup`
- `defaultgroupquota`
- `defaultuserquota`
- `devices`
- `encryption`
- `exec`
- `keysource`
- `logbias`
- `mountpoint`
- `nbmand`

- normalization
- primarycache
- quota
- readonly
- recordsize
- refquota
- refreservation
- reservation
- rstchown
- secondarycache
- setuid
- shadow
- share.nfs
- share.smb
- snapdir
- sync
- utf8only
- version
- volblocksize
- volsize
- vscan
- xattr
- zoned

Some of these properties can be set only at dataset creation time. For a description of these properties, see `zfs`(8).

## Delegating ZFS Permissions (`zfs allow`)

The `zfs allow` syntax follows:

```
zfs allow -[ldugecs] everyone|user|group[,...] perm|@setname[,...] filesystem|volume
```

The following `zfs allow` syntax (in bold) identifies to whom the permissions are delegated:

```
zfs allow [-uge]|user|group|everyone [,...] filesystem | volume
```

Multiple entities can be specified as a comma-separated list. If no `-uge` options are specified, then the argument is interpreted preferentially as the keyword `everyone`, then as a user name, and lastly, as a group name. To specify a user or group named "everyone", use the `-u` or `-g` option. To specify a group with the same name as a user, use the `-g` option. The `-c` option delegates create-time permissions.

The following `zfs allow` syntax (in bold) identifies how permissions and permission sets are specified:

```
zfs allow [-s] ... perm|@setname [,...] filesystem | volume
```

Multiple permissions can be specified as a comma-separated list. Permission names are the same as ZFS subcommands and properties. For more information, see the preceding section.

Permissions can be aggregated into *permission sets* and are identified by the `-s` option. Permission sets can be used by other `zfs allow` commands for the specified file system and its descendants. Permission sets are evaluated dynamically, so changes to a set are immediately updated. Permission sets follow the same naming requirements as ZFS file systems, but the name must begin with an at sign (`@`) and can be no more than 64 characters in length.

The following `zfs allow` syntax (in bold) identifies how the permissions are delegated:

```
zfs allow [-ld] ... ... filesystem | volume
```

The `-l` option indicates that the permissions are allowed for the specified file system and not its descendants, unless the `-d` option is also specified. The `-d` option indicates that the permissions are allowed for the descendant file systems and not for this file system, unless the `-l` option is also specified. If neither option is specified, then the permissions are allowed for the file system or volume and all of its descendants.

## Removing ZFS Delegated Permissions (`zfs unallow`)

You can remove previously delegated permissions with the `zfs unallow` command.

For example, assume that you delegated `create`, `destroy`, `mount`, and `snapshot` permissions as follows:

```
$ zfs allow mindy create,destroy,mount,snapshot system1/home/mindy
$ zfs allow system1/home/mindy
---- Permissions on system1/home/mindy --------------------------------
Local+descendant permissions:
user mindy create,destroy,mount,snapshot
```

To remove these permissions, you would use the following syntax:

```
$ zfs unallow mindy system1/home/mindy
$ zfs allow system1/home/mindy
```

# Delegating ZFS Permissions Examples

**Example 9-1 Delegating Permissions to an Individual User**

When you delegate `create` and `mount` permissions to an individual user, you must ensure that the user has permissions on the underlying mount point.

For example, to delegate user `mork` `create` and `mount` permissions on the `system1` file system, set the permissions first:

```
$ chmod A+user:mork:add_subdirectory:fd:allow /system1/home
```

Then, use the `zfs allow` command to delegate `create`, `destroy`, and `mount` permissions. For example:

```
$ zfs allow mork create,destroy,mount system1/home
```

Now, user `mork` can create his own file systems in the `system1/home` file system. For example:

```
$ su mork
mork$ zfs create system1/home/mork
mork$ ^D
$ su lp
$ zfs create system1/home/lp
cannot create 'system1/home/lp': permission denied
```

### Example 9-2 Delegating `create` and `destroy` Permissions to a Group

The following example shows how to set up a file system so that anyone in the `staff` group can create and mount file systems in the `system1/home` file system, as well as destroy their own file systems. However, `staff` group members cannot destroy anyone else's file systems.

```
$ zfs allow staff create,mount system1/home
$ zfs allow -c create,destroy system1/home
$ zfs allow system1/home
---- Permissions on system1/home --------------------------------------
Create time permissions:
create,destroy
Local+descendant permissions:
group staff create,mount
$ su mindy
mindy% zfs create system1/home/mindy/files
mindy% exit
$ su mork
mork% zfs create system1/home/mork/data
mork% exit
mindy% zfs destroy system1/home/mork/data
cannot destroy 'system1/home/mork/data': permission denied
```

### Example 9-3 Delegating Permissions at the Correct File System Level

Ensure that you delegate users permission at the correct file system level. For example, user `mork` is delegated `create`, `destroy`, and `mount` permissions for the local and descendant file systems. User `mork` is delegated local permission to snapshot the `system1/home` file system, but he is not allowed to snapshot his own file system. So, he has not been delegated the `snapshot` permission at the correct file system level.

```
$ zfs allow -l mork snapshot system1/home
$ zfs allow system1/home
---- Permissions on system1/home --------------------------------------
Create time permissions:
create,destroy
Local permissions:
user mork snapshot
Local+descendant permissions:
group staff create,mount
$ su mork
mork$ zfs snapshot system1/home@snap1
mork$ zfs snapshot system1/home/mork@snap1
cannot create snapshot 'system1/home/mork@snap1': permission denied
```

To delegate user `mork` permission at the descendant file system level, use the `zfs allow -d` command. For example:

```
$ zfs unallow -l mork snapshot system1/home
$ zfs allow -d mork snapshot system1/home
$ zfs allow system1/home
---- Permissions on system1/home --------------------------------------
```

```
Create time permissions:
create,destroy
descendant permissions:
user mork snapshot
Local+descendant permissions:
group staff create,mount
$ su mork
$ zfs snapshot system1/home@snap2
cannot create snapshot 'system1/home@snap2': permission denied
$ zfs snapshot system1/home/mork@snappy
```

Now, user `mork` can only create a snapshot below the `system1/home` file system level.

### Example 9-4 Defining and Using Complex Delegated Permissions

You can delegate specific permissions to users or groups. For example, the following `zfs allow` command delegates specific permissions to the `staff` group. In addition, `destroy` and `snapshot` permissions are delegated after `system1/home` file systems are created.

```
$ zfs allow staff create,mount system1/home
$ zfs allow -c destroy,snapshot system1/home
$ zfs allow system1/home
---- Permissions on system1/home --------------------------------------
Create time permissions:
create,destroy,snapshot
Local+descendant permissions:
group staff create,mount
```

Because user `mork` is a member of the `staff` group, he can create file systems in `system1/home`. In addition, user `mork` can create a snapshot of `system1/home/mark2` because he has specific permissions to do so. For example:

```
$ su mork
$ zfs create system1/home/mark2
$ zfs allow system1/home/mark2
---- Permissions on system1/home/mark2 --------------------------------
Local permissions:
user mork create,destroy,snapshot
---- Permissions on system1/home --------------------------------------
Create time permissions:
create,destroy,snapshot
Local+descendant permissions:
group staff create,mount
```

But, user `mork` cannot create a snapshot in `system1/home/mork` because he does not have specific permissions to do so. For example:

```
$ zfs snapshot system1/home/mork@snap1
cannot create snapshot 'system1/home/mork@snap1': permission denied
```

In this example, user `mork` has `create` permission in his home directory, which means he can create snapshots. This scenario is helpful when your file system is NFS mounted.

```
$ cd /system1/home/mark2
$ ls
$ cd .zfs
$ ls
shares snapshot
$ cd snapshot
$ ls -l
total 3
drwxr-xr-x   2 mork    staff          2 Sep 27 15:55 snap1
```

```
$ pwd
/system1/home/mark2/.zfs/snapshot
$ mkdir snap2
$ zfs list
# zfs list -r system1/home
NAME                       USED  AVAIL  REFER  MOUNTPOINT
system1/home/mork           63K  62.3G    32K  /system1/home/mork
system1/home/mark2          49K  62.3G    31K  /system1/home/mark2
system1/home/mark2@snap1    18K      -    31K  -
system1/home/mark2@snap2      0      -    31K  -
$ ls
snap1  snap2
$ rmdir snap2
$ ls
snap1
```

### Example 9-5 Defining and Using a ZFS Delegated Permission Set

The following example shows how to create the permission set `@myset` and delegates the permission set and the `rename` permission to the group `staff` for the `system1` file system. User `mindy`, a `staff` group member, has the permission to create a file system in `system1`. However, user `lp` does not have permission to create a file system in `system1`.

```
$ zfs allow -s @myset create,destroy,mount,snapshot,promote,clone,readonly \
system1
$ zfs allow system1
---- Permissions on system1 --------------------------------------------
Permission sets:
@myset clone,create,destroy,mount,promote,readonly,snapshot
$ zfs allow staff @myset,rename system1
$ zfs allow system1
---- Permissions on system1 --------------------------------------------
Permission sets:
@myset clone,create,destroy,mount,promote,readonly,snapshot
Local+descendant permissions:
group staff @myset,rename
$ chmod A+group:staff:add_subdirectory:fd:allow system1
# su mindy
mindy% zfs create system1/data
mindy% zfs allow system1
---- Permissions on system1 --------------------------------------------
Permission sets:
@myset clone,create,destroy,mount,promote,readonly,snapshot
Local+descendant permissions:
group staff @myset,rename
mindy% ls -l /system1
total 15
drwxr-xr-x   2 mindy   staff          2 Jun 24 10:55 data
mindy% exit
$ su lp
$ zfs create system1/lp
cannot create 'system1/lp': permission denied
```

# Displaying ZFS Delegated Permissions Examples

You can use the following command to display permissions:

```
$ zfs allow dataset
```

This command displays permissions that are set or allowed on the specified dataset. The output contains the following components:

- Permission sets
- Individual permissions or create-time permissions
- Local dataset
- Local and descendant datasets
- Descendant datasets only

**Example 9-6 Displaying Basic Delegated Administration Permissions**

The following output indicates that user `mindy` has `create`, `destroy`, `mount`, snapshot permissions on the `system1/mindy` file system.

```
$ zfs allow system1/mindy
-------------------------------------------------------------
Local+descendant permissions on (system1/mindy)
user mindy create,destroy,mount,snapshot
```

**Example 9-7 Displaying Complex Delegated Administration Permissions**

The output in this example indicates the following permissions on the `pool/glori` and `pool` file systems.

For the `pool/glori` file system:

- Two permission sets are defined:
  - `@eng` (`create`, `destroy`, `snapshot`, `mount`, `clone`, `promote`, `rename`)
  - `@simple` (`create`, `mount`)
- Create-time permissions are set for the `@eng` permission set and the `mountpoint` property. Create-time means that after a file system set is created, the `@eng` permission set and the permission to set the `mountpoint` property are delegated.
- User `tomi` is delegated the `@eng` permission set, and user `joe` is granted `create`, `destroy`, and `mount` permissions for local file systems.
- User `glori` is delegated the `@basic` permission set, and `share` and `rename` permissions for the local and descendant file systems.
- User `dina` and the `staff` group are delegated the `@basic` permission set for descendant file systems only.

For the `pool` file system:

- The permission set `@simple` (create, destroy, mount) is defined.
- The group `staff` is granted the `@simple` permission set on the local file system.

Here is the output for this example:

```
$ zfs allow pool/glori
---- Permissions on pool/glori --------------------------------------
Permission sets:
@eng create,destroy,snapshot,mount,clone,promote,rename
@simple create,mount
Create time permissions:
@eng,mountpoint
Local permissions:
user tomi @eng
user joe create,destroy,mount
Local+descendant permissions:
user glori @basic,share,rename
```

```
user dina @basic
group staff @basic
---- Permissions on pool -------------------------------------------
Permission sets:
@simple create,destroy,mount
Local permissions:
group staff @simple
```

# Removing ZFS Delegated Permissions Examples

You can use the `zfs unallow` command to remove delegated permissions. For example, user `mindy` has `create`, `destroy`, `mount`, and `snapshot` permissions on the `system1/mindy` file system.

```
$ zfs allow mindy create,destroy,mount,snapshot system1/home/mindy
$ zfs allow system1/home/mindy
---- Permissions on system1/home/mindy ---------------------------------
Local+descendant permissions:
user mindy create,destroy,mount,snapshot
```

The following `zfs unallow` syntax removes user `mindy`'s `snapshot` permission from the `system1/home/mindy` file system:

```
$ zfs unallow mindy snapshot system1/home/mindy
$ zfs allow system1/home/mindy
---- Permissions on system1/home/mindy ---------------------------------
Local+descendant permissions:
user mindy create,destroy,mount
mindy% zfs create system1/home/mindy/data
mindy% zfs snapshot system1/home/mindy@today
cannot create snapshot 'system1/home/mindy@today': permission denied
```

As another example, user `mork` has the following permissions on the `system1/home/mork` file system:

```
$ zfs allow system1/home/mork
---- Permissions on system1/home/mork ----------------------------------
Local+descendant permissions:
user mork create,destroy,mount
------------------------------------------------------------
```

The following `zfs unallow` syntax removes all permissions for user `mork` from the `system1/home/mork` file system:

```
$ zfs unallow mork system1/home/mork
```

The following `zfs unallow` syntax removes a permission set on the `system1` file system.

```
$ zfs allow system1
---- Permissions on system1 --------------------------------------------
Permission sets:
@myset clone,create,destroy,mount,promote,readonly,snapshot
Create time permissions:
create,destroy,mount
Local+descendant permissions:
group staff create,mount
$ zfs unallow -s @myset system1
$ zfs allow system1
---- Permissions on system1 --------------------------------------------
Create time permissions:
create,destroy,mount
```

```
Local+descendant permissions:
group staff create,mount
```

10

# Oracle Solaris ZFS Advanced Topics

This chapter describes ZFS volumes, using ZFS on an Oracle Solaris system with zones installed, ZFS alternate root pools, and ZFS rights profiles.

The chapter covers the following topics:

- ZFS Volumes.
- Using ZFS on an Oracle Solaris System With Zones Installed.
- Using a ZFS Pool With an Alternate Root Location.

## ZFS Volumes

A ZFS volume is a dataset that represents a block device. ZFS volumes are identified as devices in the `/dev/zvol/{dsk,rdsk}/rpool` directory.

In the following example, a 5GB ZFS volume, `system1/vol`, is created:

```
$ zfs create -V 5gb system1/vol
```

Be careful when changing the size of the volume. For example, if the size of the volume shrinks, data corruption might occur. In addition, if you create a snapshot of a volume that changes in size, you might introduce inconsistencies if you attempt to roll back the snapshot or create a clone from the snapshot. Thus, when you create a volume, a reservation is automatically set to the initial size of the volume to ensure data integrity.

You can display a ZFS volume's property information by using the `zfs get` or `zfs get all` command. For example:

```
$ zfs get all system1/vol
```

A question mark (?) displayed for `volsize` in the `zfs get` output indicates an unknown value because an I/O error occurred. For example:

```
$ zfs get -H volsize system1/vol
system1/vol        volsize ?       local
```

An I/O error generally indicates a problem with a pool device. For information about resolving pool device problems, see Identifying Problems With ZFS Storage Pools.

If you are using an Oracle Solaris system with zones installed, you cannot create or clone a ZFS volume in a native zone.

### Using a ZFS Volume as a Swap or Dump Device

During an installation of a ZFS root file system or a migration from a UFS root file system, a swap device and a dump device are created on a ZFS volume in the ZFS root pool. The following examples show how to display information about the swap device and the dump device.

```
$ swap -l
swapfile                   dev    swaplo   blocks     free
```

```
/dev/zvol/dsk/rpool/swap   253,3        16  8257520  8257520

$ dumpadm
Dump content: kernel pages
Dump device: /dev/zvol/dsk/rpool/dump (dedicated)
Savecore directory: /var/crash/
Savecore enabled: yes
```

If you need to change your swap area or dump device after the system is installed, use the `swap` and `dumpadm` commands as in previous Oracle Solaris releases. If you need to create an additional swap volume, create a ZFS volume of a specific size and then enable swap on that device. Then, add an entry for the new swap device in the `/etc/vfstab` file. For example:

```
$ zfs create -V 2G rpool/swap2
$ swap -a /dev/zvol/dsk/rpool/swap2
$ swap -l
swapfile                      dev  swaplo  blocks    free
/dev/zvol/dsk/rpool/swap    256,1      16 2097136 2097136
/dev/zvol/dsk/rpool/swap2   256,5      16 4194288 4194288
```

Do not swap to a file on a ZFS file system. A ZFS swap file configuration is not supported.

For information about adjusting the size of the swap and dump volumes, see Adjusting the Sizes of ZFS Swap and Dump Devices.

# Using a ZFS Volume as an iSCSI LUN

A ZFS volume as an iSCSI target is managed just like any other ZFS dataset, except that you cannot rename the dataset, roll back a volume snapshot, or export the pool while the ZFS volumes are shared as iSCSI LUNs. If you attempt to perform those operations, messages similar to the following are displayed:

```
$ zfs rename system1/volumes/v2 system1/volumes/v1
cannot rename 'system1/volumes/v2': dataset is busy
$ zpool export system1
cannot export 'system1': pool is busy
```

All iSCSI target configuration information is stored within the dataset. Like an NFS shared file system, an iSCSI target that is imported on a different system is shared appropriately.

The Common Multiprotocol SCSI Target (COMSTAR) software framework enables you to convert any Oracle Solaris system into a SCSI target device that can be accessed over a storage network by initiator hosts. You can create and configure a ZFS volume to be shared as an iSCSI logical unit (LUN).

## How to Use a ZFS Volume as an iSCSI LUN

1. **First, install the COMSTAR package.**

   ```
   $ pkg install group/feature/storage-server
   ```

2. **Create a ZFS volume to be used as an iSCSI target.**

   For example:

   ```
   $ zfs create -V 2g system1/volumes/v2
   ```

3. **Create the SCSI-block-device-based LUN.**

   For example:

```
$ sbdadm create-lu /dev/zvol/rdsk/system1/volumes/v2
Created the following LU:

GUID                    DATA SIZE           SOURCE
--------------------------------  ----------------  ----------------
600144f000144f1dafaa4c0faff20001  2147483648          /dev/zvol/rdsk/system1/
volumes/v2
$ sbdadm list-lu
Found 1 LU(s)

GUID                    DATA SIZE           SOURCE
--------------------------------  ----------------  ----------------
600144f000144f1dafaa4c0faff20001  2147483648          /dev/zvol/rdsk/system1/
volumes/v2
```

4. **Share LUN views to all ZFS clients. or selected ZFS clients.**

   You can expose the LUN views to all ZFS clients or to a selected list of ZFS clients. In the following example, the LUN view is shared to all ZFS clients.

   a. **Identify the LUN GUID.**

   ```
   $ stmfadm list-lu
   LU Name: 600144F000144F1DAFAA4C0FAFF20001
   ```

   b. **Share the LUN view.**

   ```
   $ stmfadm add-view 600144F000144F1DAFAA4C0FAFF20001
   $ stmfadm list-view -l 600144F000144F1DAFAA4C0FAFF20001
   View Entry: 0
   Host group   : All
   Target group : All
   LUN          : 0
   ```

5. **Create the iSCSI targets.**

   For information about creating the iSCSI targets, see Chapter 8, Configuring Storage Devices With COMSTAR in *Managing Devices in Oracle Solaris 11.4* .

# Using ZFS on an Oracle Solaris System With Zones Installed

The Oracle Solaris Zones feature in the Oracle Solaris operating system provides an isolated environment in which to run applications on your system. The following sections describe how to use ZFS on a system with Oracle Solaris zones:

- Adding ZFS File Systems to a Non-Global Zone.
- Delegating Datasets to a Non-Global Zone.
- Adding ZFS Volumes to a Non-Global Zone.
- Using ZFS Storage Pools Within a Zone.
- Managing ZFS Properties Within a Zone.
- Understanding the zoned Property.

Keep the following points in mind when associating ZFS datasets with zones:

- You can add a ZFS file system or a clone to a native zone with or without delegating administrative control.
- You can add a ZFS volume as a device to native zones.
- You cannot associate ZFS snapshots with zones at this time.

> **Note:**
>
> Oracle Solaris kernel zones use storage differently from native Oracle Solaris zones. For more information about storage use in kernel zones, see the Storage Access section of the `solaris-kz`(7) man page. For information about storage use on shared storage, see Chapter 13, Oracle Solaris Zones on Shared Storage in *Creating and Using Oracle Solaris Zones* .

Adding a ZFS filesystem by using an `fs` resource enables the native zone to share disk space with the global or kernel zone. However, the zone administrator cannot control properties or create new file systems in the underlying file system hierarchy. This operation is identical to adding any other type of file system to a zone. You should add a file system to a native zone only for the sole purpose of sharing common disk space.

You can also delegate ZFS datasets to a native zone, which would give the zone administrator complete control over the dataset and all its children. The zone administrator can create and destroy file systems or clones within that dataset, as well as modify properties of the datasets. The zone administrator cannot affect datasets that have not been added to the zone, including exceeding any top-level quotas set on the delegated dataset.

When both a source `zonepath` and a target `zonepath` reside on a ZFS file system and are in the same pool, the `zoneadm clone` command, not `zfs clone`, becomes the command for cloning zones. The `zoneadm clone` command creates a ZFS snapshot of the source `zonepath` and sets up the target `zonepath`. For more information, see *Creating and Using Oracle Solaris Zones* .

## Adding ZFS File Systems to a Non-Global Zone

A ZFS file system that is added to a native zone must have its `mountpoint` property set to `legacy`. For example, for the `system1/zone/zion` file system, you would type the following command on the global or kernel zone:

```
global$ zfs set mountpoint=legacy system1/zone/zion
```

Then you would add that file system to the native zone by using the `add fs` subcommand of the `zonecfg` command.

> **Note:**
>
> To add the files system, ensure that it is not previously mounted on another location.

```
global$ zonecfg -z zion
zonecfg:zion> add fs
zonecfg:zion:fs> set type=zfs
zonecfg:zion:fs> set special=system1/zone/zion
zonecfg:zion:fs> set dir=/opt/data
zonecfg:zion:fs> end
```

This syntax adds the ZFS file system, `system1/zone/zion`, to the already configured `zion` zone, which is mounted at `/opt/data`. The zone administrator can create and destroy files within the file system. The file system cannot be remounted to a different location. Likewise, the zone administrator cannot change properties on the file system such as `atime`, `readonly`, `compression`, and so on.

The global zone administrator is responsible for setting and controlling properties of the file system.

For more information about the `zonecfg` command and about configuring resource types with `zonecfg`, see *Creating and Using Oracle Solaris Zones* .

## Delegating Datasets to a Non-Global Zone

To meet the primary goal of delegating the administration of storage to a zone, ZFS supports adding datasets to a native zone through the use of the `zonecfg add dataset` command.

In the following example, a ZFS file system is delegated to a native zone by a global zone administrator from the global zone or kernel zone.

```
global$ zonecfg -z zion
zonecfg:zion> add dataset
zonecfg:zion:dataset> set name=system1/zone/zion
zonecfg:zion:dataset> set alias=system1
zonecfg:zion:dataset> end
```

Unlike adding a file system, this syntax causes the ZFS file system `system1/zone/zion` to be visible within the already configured `zion` zone. Within the `zion` zone, this file system is not accessible as `system1/zone/zion`, but as a *virtual pool* named `system1`. The delegated file system alias provides a view of the original pool to the zone as a virtual pool. The alias property specifies the name of the virtual pool. If no alias is specified, a default alias matching the last component of the file system name is used. In the example, the default alias would be `zion`.

Within delegated datasets, the zone administrator can set file system properties, as well as create descendant file systems. In addition, the zone administrator can create snapshots and clones, and otherwise control the entire file system hierarchy. If ZFS volumes are created within delegated file systems, these volumes might conflict with ZFS volumes that are added as device resources.

## Adding ZFS Volumes to a Non-Global Zone

You can add or create a ZFS volume in a native zone or you can add access to a volume's data in a native zone in the following ways:

- In a native zone, a privileged zone administrator can create a ZFS volume as descendant of a previously delegated file system. For example, you can type the following command for the file system `system1/zone/zion` that was delegated in the previous example:

  ```
  $ zfs create -V 2g system1/zone/zion/vol1
  ```

  After the volume is created, the zone administrator can manage the volume's properties and data in the native zone as well as create snapshots.

- In a global or kernel zone, use the `zonecfg add device` command and specify a ZFS volume whose data can be accessed in a native zone. For example:

  ```
  global$ zonecfg -z zion
  zonecfg:zion> add device
  zonecfg:zion:device> set match=/dev/zvol/dsk/system1/volumes/vol2
  zonecfg:zion:device> end
  ```

  In this example, only the volume data can be accessed in the native zone.

# Using ZFS Storage Pools Within a Zone

ZFS storage pools cannot be created or modified within a native zone. The delegated administration model centralizes control of physical storage devices within the global or kernel zone and control of virtual storage to native zones. Although a pool-level dataset can be added to a native zone, any command that modifies the physical characteristics of the pool, such as creating, adding, or removing devices, is not allowed from within a native zone. Even if physical devices are added to a native zone by using the `zonecfg add device` command, or if files are used, the `zpool` command does not allow the creation of any new pools within the native zone.

Kernel zones are more powerful and more flexible in terms of data storage management. Devices and volumes can be delegated to a kernel zone, much like a global zone. Also, a ZFS storage pool can be created in a kernel zone.

# Managing ZFS Properties Within a Zone

After a dataset is delegated to a zone, the zone administrator can control specific dataset properties. After a dataset is delegated to a zone, all its ancestors are visible as read-only datasets, while the dataset itself is writable, as are all of its descendants. For example, consider the following configuration:

```
global$ zfs list -Ho name
system1
system1/home
system1/data
system1/data/matrix
system1/data/zion
system1/data/zion/home
```

If `system1/data/zion` were added to a zone with the default `zion` alias, each dataset would have the following properties.

| Dataset | Visible | Writable | Immutable Properties |
|---|---|---|---|
| `system1` | No | - | - |
| `system1/home` | No | - | - |
| `system1/data` | No | - | - |
| `system1/data/zion` | Yes | Yes | `zoned`, `quota`, `reservation` |
| `system1/data/zion/home` | Yes | Yes | `zoned` |

Note that every parent of `system1/zone/zion` is invisible and all descendants are writable. The zone administrator cannot change the `zoned` property because doing so would expose a security risk that described in the next section.

Privileged users in the zone can change any other settable property, except for `quota` and `reservation` properties. This behavior allows the global zone administrator to control the disk space consumption of all datasets used by the native zone.

In addition, the `share.nfs` and `mountpoint` properties cannot be changed by the global zone administrator after a dataset has been delegated to a native zone.

# Understanding the zoned Property

When a dataset is delegated to a native zone, the dataset must be specially marked so that certain properties are not interpreted within the context of the global or kernel zone. After a dataset has been delegated to a native zone and is under the control of a zone administrator, its contents can no longer be trusted. As with any file system, setuid binaries, symbolic links, or otherwise questionable contents might exist that might adversely affect the security of the global or kernel zone. In addition, the mountpoint property cannot be interpreted in the context of the global or kernel zone. Otherwise, the zone administrator could affect the global or kernel zone's namespace. To address the latter, ZFS uses the zoned property to indicate that a dataset has been delegated to a native zone at one point in time.

The zoned property is a boolean value that is automatically turned on when a zone containing a ZFS dataset is first booted. A zone administrator does not need to manually set this property. If the zoned property is set, the dataset cannot be mounted or shared in the global or kernel zone. In the following example, system1/zone/zion has been delegated to a zone, while system1/zone/global has not:

```
$ zfs list -o name,zoned,mountpoint -r system1/zone
NAME                  ZONED   MOUNTPOINT              MOUNTED
system1/zone/global     off   /system1/zone/global        yes
system1/zone/zion        on   /system1/zone/zion          yes
$ zfs mount
system1/zone/global           /system1/zone/global
system1/zone/zion             /export/zone/zion/root/system1/zone/zion

root@kzx-05:~# zonecfg -z sol info
dataset
dataset:
    name: rpool/foo
    alias: foo
root@kzx-05:~# zfs list -o name,zoned,mountpoint,mounted -r
rpool/foo
NAME       ZONED  MOUNTPOINT                  MOUNTED
rpool/foo     on  /system/zones/sol/root/foo      yes
root@kzx-05:~# zfs mount | grep /foo
rpool/foo                      /system/zones/sol/root/foo
```

When a dataset is removed from a zone or a zone is destroyed, the zoned property is *not* automatically cleared. This behavior would avoid the inherent security risks associated with these tasks. Because an untrusted user has complete access to the dataset and its descendants, the mountpoint property might be set to bad values, or setuid binaries might exist on the file systems.

To prevent accidental security risks, the zoned property must be manually cleared by the global zone administrator if you want to reuse the dataset in any way. Before setting the zoned property to off, ensure that the mountpoint property for the dataset and all its descendants are set to reasonable values and that no setuid binaries exist, or turn off the setuid property.

After you have verified that no security vulnerabilities are left, the zoned property can be turned off by using the zfs set or zfs inherit command. If the zoned property is turned off while a dataset is in use within a zone, the system might behave in unpredictable ways. Only change the property if you are sure the dataset is no longer in use by a native zone.

## Copying Zones to Other Systems

When you need to migrate one or more zones needs to another system, use Oracle Solaris Unified Archives, which manage all cloning and recovery operations in the operating system and which operate on global, native, as well as kernel zones. For more information about Unified Archives, see *Using Unified Archives for System Recovery and Cloning in Oracle Solaris 11.4* . For instructions about migrating zones, which include copying zones to other systems, see Chapter 10, Transforming Systems to Oracle Solaris Zones in *Creating and Using Oracle Solaris Zones* .

If all zones on one system need to move to another ZFS pool on a different system, consider using a replication stream because it preserves snapshots and clones. Snapshots and clones are used extensively by `pkg update`, `beadm create`, and the `zoneadm clone` commands.

In the following example, the `sysA`'s zones are installed in the `rpool/zones` file system and they need to be copied to the `newpool/zones` file system on `sysB`. The following commands create a snapshot and copy the data to `sysB` by using a replication stream:

```
sysA$ zfs snapshot -r rpool/zones@send-to-sysB
sysA$ zfs send -R rpool/zones@send-to-sysB | ssh sysB zfs receive -d newpool
```

> **Note:**
>
> The commands refer only to the ZFS aspect of the operation. You would need to perform other zones-related command to complete the task. For specific information, refer to Chapter 10, Transforming Systems to Oracle Solaris Zones in *Creating and Using Oracle Solaris Zones* .

# Using a ZFS Pool With an Alternate Root Location

A pool is intrinsically tied to the host system. The host system maintains information about the pool so that it can detect when the pool is unavailable. Although useful for normal operations, this information can prove a hindrance when you are booting from alternate media or creating a pool on removable media. To solve this problem, ZFS provides an *alternate root location* pool feature. An alternate root pool location does not persist across system reboots, and all mount points are modified to be relative to the root of the pool.

## Creating a ZFS Pool With an Alternate Root Location

The most common reason for creating a pool at an alternate location is for use with removable media. In these circumstances, users typically want a single file system, and they want it to be mounted wherever they choose on the target system. When a pool is created by using the `zpool create -R` command, the mount point of the root file system is automatically set to `/`, which is the equivalent of the alternate root value.

In the following example, a pool called `morpheus` is created with `/mnt` as the alternate root location:

```
$ zpool create -R /mnt morpheus c0t0d0
$ zfs list morpheus
NAME                  USED  AVAIL  REFER  MOUNTPOINT
morpheus             32.5K  33.5G     8K  /mnt
```

Note the single file system, `morpheus`, whose mount point is the alternate root location of the pool, `/mnt`. The mount point that is stored on disk is `/` and the full path to `/mnt` is interpreted only in this initial context of the pool creation. This file system can then be exported and imported under an arbitrary alternate root location on a different system by using `-R` *alternate-root-value* syntax.

```
$ zpool export morpheus
$ zpool import morpheus
cannot mount '/': directory is not empty
$ zpool export morpheus
$ zpool import -R /mnt morpheus
$ zfs list morpheus
NAME                   USED  AVAIL  REFER  MOUNTPOINT
morpheus              32.5K  33.5G     8K  /mnt
```

## Importing a Pool With an Alternate Root Location

Pools can also be imported using an alternate root location. This feature allows for recovery situations, where the mount points should not be interpreted in context of the current root mount point, but under some temporary directory where repairs can be performed. This feature also can be used when you are mounting removable media as described in the preceding section.

In the following example, a pool called `morpheus` is imported with `/mnt` as the alternate root mount point. This example assumes that `morpheus` was previously exported.

```
$ zpool import -R /a pool
$ zpool list morpheus
NAME   SIZE   ALLOC  FREE    CAP  HEALTH  ALTROOT
pool  44.8G    78K  44.7G     0%  ONLINE  /a
$ zfs list pool
NAME   USED  AVAIL  REFER  MOUNTPOINT
pool  73.5K  44.1G    21K  /a/pool
```

## Importing a Pool With a Temporary Name

In addition to importing a pool at an alternate root location, you can import a pool with a temporary name. In certain shared storage or recovery situations, this feature allows two pools with the same persistent name to be simultaneously imported. One of those pools must be imported with a temporary name.

In the following example, the `rpool` pool is imported at an alternate root location and with a temporary name. Because the persistent pool name conflicts with a pool that is already imported, it must be imported by pool ID or by specifying the devices.

```
$ zpool import
pool: rpool
id: 16760479674052375628
state: ONLINE
action: The pool can be imported using its name or numeric identifier.
config:

rpool     ONLINE
c8d1s0  ONLINE
$ zpool import -R /a -t altrpool 16760479674052375628
$ zpool list
NAME      SIZE  ALLOC  FREE  CAP  DEDUP  HEALTH  ALTROOT
altrpool   97G  22.4G   74G  23%  1.00x  ONLINE  /a
rpool     465G  75.1G  390G  16%  1.00x  ONLINE  -
```

A pool can also be created with a temporary name by using the `zpool create -t` command.

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# Oracle Solaris ZFS Troubleshooting and Pool Recovery

This chapter describes how to identify and recover from ZFS failures. Information for preventing failures is provided as well.

This chapter covers the following topics:

- Identifying ZFS Problems.
- Resolving General Hardware Problems.
- Identifying Problems With ZFS Storage Pools.
- Resolving ZFS Storage Device Problems.
- Resolving Data Problems in a ZFS Storage Pool.
- Repairing a Damaged ZFS Configuration.
- Repairing an Unbootable System.

For information about complete root pool recovery, see *Using Unified Archives for System Recovery and Cloning in Oracle Solaris 11.4* .

## Identifying ZFS Problems

As a combined file system and volume manager, ZFS can exhibit many different failures. This chapter outlines how to diagnose general hardware failures and then how to resolve pool device and file system problems. You can encounter the following types of problems:

- **General Hardware Problems** – Hardware problems can impact your pool performance and the availability of your pool data. Rule out general hardware problems, such as faulty components and memory, before determining problems at a higher level, such as your pools and file systems.
- **ZFS storage pool problems**
  - Identifying Problems With ZFS Storage Pools.
  - Resolving ZFS Storage Device Problems.
- **Data is corrupted** – Resolving Data Problems in a ZFS Storage Pool.
- **Configuration is damaged** – Repairing a Damaged ZFS Configuration.
- **System won't boot** – Repairing an Unbootable System.

Note that a single pool can experience all three errors, so a complete repair procedure involves finding and correcting one error, proceeding to the next error, and so on.

## Resolving General Hardware Problems

Review the following sections to determine whether pool problems or file system unavailability is related to a hardware problem, such as faulty system board, memory, device, HBA, or a misconfiguration.

For example, a failing or faulty disk on a busy ZFS pool can greatly degrade overall system performance.

If you start by diagnosing and identifying hardware problems first, which can be easier to detect and all your hardware checks out, you can then move on to diagnosing pool and file system problems as described in the rest of this chapter. If your hardware, pool, and file system configurations are healthy, consider diagnosing application problems, which are generally more complex to unravel and are not covered in this guide.

## Identifying Hardware and Device Faults

The Oracle Solaris Fault Manager tracks software, hardware and specific device problems by identifying error telemetry information that indicate a specific symptom in an error log and then reporting actual fault diagnosis when the error symptom results in an actual fault.

The following command identifies any software or hardware related fault.

```
$ fmadm faulty
```

Use the above command routinely to identify failed services or devices.

Use the following command routinely to identify hardware or device related errors.

```
$ fmdump -eV | more
```

Error messages in this log file that describe `vdev.open_failed`, `checksum`, or `io_failure` issues need your attention or they might evolve into actual faults that are displayed with the `fmadm` faulty command.

If the above indicates that a device is failing, then this is a good time to make sure you have a replacement device available.

You can also track additional device errors by using `iostat` command. Use the following syntax to identify a summary of error statistics.

```
$ iostat -en
---- errors ---
s/w h/w trn tot device
0   0   0   0 c0t5000C500335F95E3d0
0   0   0   0 c0t5000C500335FC3E7d0
0   0   0   0 c0t5000C500335BA8C3d0
0  12   0  12 c2t0d0
0   0   0   0 c0t5000C500335E106Bd0
0   0   0   0 c0t50015179594B6F11d0
0   0   0   0 c0t5000C500335DC60Fd0
0   0   0   0 c0t5000C500335F907Fd0
0   0   0   0 c0t5000C500335BD117d0
```

In the above output, errors are reported on an internal disk `c2t0d0`. Use the following syntax to display more detailed device errors.

## Resolving Persistent or Transient Transport Errors

Persistent SCSI transport errors that refer to retries or resets can be caused by down-rev firmware, a bad disk, a bad cable, or a faulty hardware connection. Some transient transport errors can be resolved by upgrading your HBA or device firmware. If transport errors persist after firmware is updated and all devices are deemed operational, then look for a bad cable or other faulty connection between hardware components.

## System Reporting of ZFS Error Messages

In addition to persistently tracking errors within the pool, ZFS also displays `syslog` messages when events of interest occur. The following scenarios generate notification events:

- **Device state transition** – If a device becomes `FAULTED`, ZFS logs a message indicating that the fault tolerance of the pool might be compromised. A similar message is sent if the device is later brought online, restoring the pool to health.
- **Data corruption** – If any data corruption is detected, ZFS logs a message describing when and where the corruption was detected. This message is only logged the first time it is detected. Subsequent accesses do not generate a message.
- **Pool failures and device failures** – If a pool failure or a device failure occurs, the fault manager daemon reports these errors through `syslog` messages as well as the `fmdump` command.

If ZFS detects a device error and automatically recovers from it, no notification occurs. Such errors do not constitute a failure in the pool redundancy or in data integrity. Moreover, such errors are typically the result of a driver problem accompanied by its own set of error messages.

# Identifying Problems With ZFS Storage Pools

You can use the following features to identify problems with your ZFS configuration:

- Detailed ZFS storage pool information can be displayed by using the `zpool status` command.
- Pool and device failures are reported through ZFS/FMA diagnostic messages.
- Previous ZFS commands that modified pool state information can be displayed by using the `zpool history` command.
- A ZFS storage pool that is accidentally destroyed can be recovered by using the `zpool import -D` command, but its important that the pool is recovered quickly so that the devices are not reused or accidentally overwritten. For more information, see Recovering Destroyed ZFS Storage Pools. No similar feature exists to recover ZFS file systems or data. Always have good backups.

Most ZFS troubleshooting involves the `zpool status` command. This command analyzes the various failures in a system and identifies the most severe problem, presenting you with a suggested action and a link to a knowledge article for more information. Note that the command only identifies a single problem with a pool, though multiple problems can exist. For example, data corruption errors generally imply that one of the devices has failed, but replacing the failed device might not resolve all of the data corruption problems.

In addition, a ZFS diagnostic engine diagnoses and reports pool failures and device failures. Checksum, I/O, device, and pool errors associated with these failures are also reported. ZFS failures as reported by `fmd` are displayed on the console as well as the system messages file. In most cases, the `fmd` message directs you to the `zpool status` command for further recovery instructions.

The basic recovery process is as follows:

- If appropriate, use the `zpool history` command to identify the ZFS commands that preceded the error scenario. For example:

```
$ zpool history system1
History for 'system1':
2012-11-12.13:01:31 zpool create system1 mirror c0t1d0 c0t2d0 c0t3d0
2012-11-12.13:28:10 zfs create system1/glori
2012-11-12.13:37:48 zfs set checksum=off system1/glori
```

In this output, note that checksums are disabled for the `system1/glori` file system. This configuration is not recommended.

- Identify the errors through the `fmd` messages that are displayed on the system console or in the `/var/adm/messages` file.
- Find further repair instructions by using the `zpool status -x` command.
- Repair the failures, which involves the following steps:
  - Replacing the unavailable or missing device and bring it online.
  - Restoring the faulted configuration or corrupted data from a backup.
  - Verifying the recovery by using the `zpool status -x` command.
  - Backing up your restored configuration, if applicable.

This section describes how to interpret `zpool status` output in order to diagnose the type of failures that can occur. Although most of the work is performed automatically by the command, it is important to understand exactly what problems are being identified in order to diagnose the failure. Subsequent sections describe how to repair the various problems that you might encounter.

## Determining If Problems Exist in a ZFS Storage Pool

The easiest way to determine if any known problems exist on a system is to use the `zpool status -x` command. This command describes only pools that are exhibiting problems. If no unhealthy pools exist on the system, then the command displays the following:

```
$ zpool status -x
all pools are healthy
```

Without the `-x` flag, the command displays the complete status for all pools (or the requested pool, if specified on the command line), even if the pools are otherwise healthy.

For more information about command-line options to the `zpool status` command, see Querying ZFS Storage Pool Status.

## Reviewing ZFS Storage Pool Status Information

ZFS storage pool status information is displayed by using the `zpool status` command. For example:

```
$ zpool status pond
pool: pond
state: DEGRADED
status: One or more devices are unavailable in response to persistent errors.
Sufficient replicas exist for the pool to continue functioning in a
degraded state.
action: Determine if the device needs to be replaced, and clear the errors
using 'zpool clear' or 'fmadm repaired', or replace the device
with 'zpool replace'.
Run 'zpool status -v' to see device specific details.
scan: scrub repaired 0 in 0h0m with 0 errors on Wed Jun 20 13:16:09 2012
config:
```

```
NAME                    STATE     READ WRITE CKSUM
pond                    DEGRADED     0     0     0
mirror-0                ONLINE       0     0     0
c0t5000C500335F95E3d0   ONLINE       0     0     0
c0t5000C500335F907Fd0   ONLINE       0     0     0
mirror-1                DEGRADED     0     0     0
c0t5000C500335BD117d0   ONLINE       0     0     0
c0t5000C500335DC60Fd0   UNAVAIL      0     0     0

errors: No known data errors
```

This output is described in the following section.

## Overall Pool Status Information

This section in the `zpool status` output contains the following fields, some of which are only displayed for pools exhibiting problems:

**`pool`**
Identifies the name of the pool.

**`state`**
Indicates the current health of the pool. This information refers only to the ability of the pool to provide the necessary replication level.

**`status`**
Describes what is wrong with the pool. This field is omitted if no errors are found.

**`action`**
A recommended action for repairing the errors. This field is omitted if no errors are found.

**`see`**
Refers to a knowledge article containing detailed repair information. Online articles are updated more often than this guide can be updated. So, always reference them for the most up-to-date repair procedures. This field is omitted if no errors are found.

**`scrub`**
Identifies the current status of a scrub operation, which might include the date and time that the last scrub was completed, a scrub is in progress, or if no scrub was requested.

**`errors`**
Identifies known data errors or the absence of known data errors.

## ZFS Storage Pool Configuration Information

The `config` field in the `zpool status` output describes the configuration of the devices in the pool, as well as their state and any errors generated from the devices. The state can be one of the following: `ONLINE`, `FAULTED`, `DEGRADED`, or `SUSPENDED`. If the state is anything but `ONLINE`, the fault tolerance of the pool has been compromised.

The second section of the configuration output displays error statistics. These errors are divided into three categories:

- `READ` – I/O errors that occurred while issuing a read request
- `WRITE` – I/O errors that occurred while issuing a write request

- `CKSUM` – Checksum errors, meaning that the device returned corrupted data as the result of a read request

These errors can be used to determine if the damage is permanent. A small number of I/O errors might indicate a temporary outage, while a large number might indicate a permanent problem with the device. These errors do not necessarily correspond to data corruption as interpreted by applications. If the device is in a redundant configuration, the devices might show uncorrectable errors, while no errors appear at the mirror or RAID-Z device level. In such cases, ZFS successfully retrieved the good data and attempted to heal the damaged data from existing replicas.

For more information about interpreting these errors, see Determining the Type of Device Failure.

Finally, additional auxiliary information is displayed in the last column of the `zpool status` output. This information expands on the `state` field, aiding in the diagnosis of failures. If a device is `UNAVAIL`, this field indicates whether the device is inaccessible or whether the data on the device is corrupted. If the device is undergoing resilvering, this field displays the current progress.

For information about monitoring resilvering progress, see Viewing Resilvering Status.

## ZFS Storage Pool Scrubbing Status

The scrub section of the `zpool status` output describes the current status of any scrubbing operations. This information is distinct from whether any errors are detected on the system, though this information can be used to determine the accuracy of the data corruption error reporting. If the last scrub ended recently, most likely, any known data corruption has been discovered.

The following `zpool status` scrub status messages are provided:

- Scrub in-progress report. For example:

```
scan: scrub in progress since Wed Jun 20 14:56:52 2012
529M scanned out of 71.8G at 48.1M/s, 0h25m to go
0 repaired, 0.72% done
```

- Scrub completion message. For example:

```
scan: scrub repaired 0 in 0h11m with 0 errors on Wed Jun 20 15:08:23 2012
```

- Ongoing scrub cancellation message. For example:

```
scan: scrub canceled on Wed Jun 20 16:04:40 2012
```

Scrub completion messages persist across system reboots.

For more information about the data scrubbing and how to interpret this information, see Checking ZFS File System Integrity.

## ZFS Data Corruption Errors

The `zpool status` command also shows whether any known errors are associated with the pool. These errors might have been found during data scrubbing or during normal operation. ZFS maintains a persistent log of all data errors associated with a pool. This log is rotated whenever a complete scrub of the system finishes.

Data corruption errors are always fatal. Their presence indicates that at least one application experienced an I/O error due to corrupt data within the pool. Device errors within a redundant pool do not result in data corruption and are not recorded as part of this log. By default, only

the number of errors found is displayed. A complete list of errors and their specifics can be found by using the `zpool status -v` command. For example:

```
$ zpool status -v system1
pool: system1
state: ONLINE
status: One or more devices has experienced an error resulting in data
corruption.  Applications may be affected.
action: Restore the file in question if possible. Otherwise restore the
entire pool from backup.
see: http://support.oracle.com/msg/ZFS-8000-8A
scan: scrub repaired 0 in 0h0m with 2 errors on Fri Jun 29 16:58:58 2012
config:

NAME           STATE     READ WRITE CKSUM
system1        ONLINE       2     0     0
   c8t0d0      ONLINE       0     0     0
   c8t1d0      ONLINE       2     0     0

errors: Permanent errors have been detected in the following files:

/system1/file.1
```

A similar message is also displayed by `fmd` on the system console and the `/var/adm/messages` file. These messages can also be tracked by using the `fmdump` command.

For more information about interpreting data corruption errors, see Identifying the Type of Data Corruption.

# Resolving ZFS Storage Device Problems

Review the following sections to resolve a missing, removed or faulted device.

## Resolving a Missing or Removed Device

If a device cannot be opened, it displays the `UNAVAIL` state in the `zpool status` output. This state means that ZFS was unable to open the device when the pool was first accessed, or the device has since become unavailable. If the device causes a top-level virtual device to be unavailable, then nothing in the pool can be accessed. Otherwise, the fault tolerance of the pool might be compromised. In either case, the device just needs to be reattached to the system to restore normal operations. If you need to replace a device that is `UNAVAIL` because it has failed, see Replacing a Device in a ZFS Storage Pool.

If a device is `UNAVAIL` in a root pool or a mirrored root pool, see the following references:

- **Mirrored root pool disk failed** – Booting From an Alternate Root Pool Disk
- **Replacing a disk in a root pool** – How to Replace a Disk in a ZFS Root Pool
- **Full root pool disaster recovery** – *Using Unified Archives for System Recovery and Cloning in Oracle Solaris 11.4*

For example, you might see a message similar to the following from `fmd` after a device failure:

```
SUNW-MSG-ID: ZFS-8000-QJ, TYPE: Fault, VER: 1, SEVERITY: Minor
EVENT-TIME: Wed Jun 20 13:09:55 MDT 2012
...
SOURCE: zfs-diagnosis, REV: 1.0
EVENT-ID: e13312e0-be0a-439b-d7d3-cddaefe717b0
DESC: Outstanding dtls on ZFS device 'id1,sd@n5000c500335dc60f/a' in pool 'pond'.
```

```
AUTO-RESPONSE: No automated response will occur.
IMPACT: None at this time.
REC-ACTION: Use 'fmadm faulty' to provide a more detailed view of this event.
Run 'zpool status -lx' for more information. Please refer to the associated
reference document at http://support.oracle.com/msg/ZFS-8000-QJ for the latest
service procedures and policies regarding this diagnosis.
```

To view more detailed information about the device problem and the resolution, use the `zpool status -v` command. For example:

```
$ zpool status -v
pool: pond
state: DEGRADED
status: One or more devices are unavailable in response to persistent errors.
Sufficient replicas exist for the pool to continue functioning in a
degraded state.
action: Determine if the device needs to be replaced, and clear the errors
using 'zpool clear' or 'fmadm repaired', or replace the device
with 'zpool replace'.
scan: scrub repaired 0 in 0h0m with 0 errors on Wed Jun 20 13:16:09 2012
config:

NAME                    STATE     READ WRITE CKSUM
pond                    DEGRADED     0     0     0
mirror-0                ONLINE       0     0     0
c0t5000C500335F95E3d0   ONLINE       0     0     0
c0t5000C500335F907Fd0   ONLINE       0     0     0
mirror-1                DEGRADED     0     0     0
c0t5000C500335BD117d0   ONLINE       0     0     0
c0t5000C500335DC60Fd0   UNAVAIL      0     0     0

device details:

c0t5000C500335DC60Fd0    UNAVAIL          cannot open
status: ZFS detected errors on this device.
The device was missing.
see: http://support.oracle.com/msg/ZFS-8000-LR for recovery
```

You can see from this output that the `c0t5000C500335DC60Fd0` device is not functioning. If you determine that the device is faulty, replace it.

If necessary, use the `zpool online` command to bring the replaced device online. For example:

```
$ zpool online pond c0t5000C500335DC60Fd0
```

Let FMA know that the device has been replaced if the output of the `fmadm faulty` identifies the device error. For example:

```
$ fmadm faulty
--------------- ------------------------------------  -------------- ---------
TIME            EVENT-ID                              MSG-ID         SEVERITY
--------------- ------------------------------------  -------------- ---------
Jun 20 13:15:41 3745f745-371c-c2d3-d940-93acbb881bd8  ZFS-8000-LR    Major

Problem Status    : solved
Diag Engine       : zfs-diagnosis / 1.0
System
Manufacturer  : unknown
Name          : ORCL,SPARC-T3-4
Part_Number   : unknown
Serial_Number : 1120BDRCCD
```

```
Host_ID       : 84a02d28

----------------------------------------
Suspect 1 of 1 :
Fault class : fault.fs.zfs.open_failed
Certainty   : 100%
Affects     : zfs://pool=86124fa573cad84e/
  vdev=25d36cd46e0a7f49/pool_name=pond/
  vdev_name=id1,sd@n5000c500335dc60f/a
Status      : faulted and taken out of service

FRU
Name             : "zfs://pool=86124fa573cad84e/
vdev=25d36cd46e0a7f49/pool_name=pond/
vdev_name=id1,sd@n5000c500335dc60f/a"
Status        : faulty

Description : ZFS device 'id1,sd@n5000c500335dc60f/a'
in pool 'pond' failed to open.

Response    : An attempt will be made to activate a hot spare if available.

Impact      : Fault tolerance of the pool may be compromised.

Action      : Use 'fmadm faulty' to provide a more detailed view of this event.
Run 'zpool status -lx' for more information. Please refer to the
associated reference document at
http://support.oracle.com/msg/ZFS-8000-LR for the latest service
procedures and policies regarding this diagnosis.
```

Extract the string in the `Affects:` section of the `fmadm faulty` output and include it with the following command to let FMA know that the device is replaced:

```
$ fmadm repaired zfs://pool=86124fa573cad84e/ \
   vdev=25d36cd46e0a7f49/pool_name=pond/ \
   vdev_name=id1,sd@n5000c500335dc60f/a
fmadm: recorded repair to of zfs://pool=86124fa573cad84e/
   vdev=25d36cd46e0a7f49/pool_name=pond/vdev_
name=id1,sd@n5000c500335dc60f/a
```

As a last step, confirm that the pool with the replaced device is healthy. For example:

```
$ zpool status -x system1
pool 'system1' is healthy
```

## Resolving a Removed Device

If a device is completely removed from the system, ZFS detects that the device cannot be opened and places it in the `REMOVED` state. Depending on the data replication level of the pool, this removal might or might not result in the entire pool becoming unavailable. If one disk in a mirrored or RAID-Z device is removed, the pool continues to be accessible. A pool might become `UNAVAIL`, which means no data is accessible until the device is reattached, under the following conditions:

If a redundant storage pool device is accidentally removed and reinserted, then you can just clear the device error, in most cases. For example:

```
$ zpool clear system1 c1t1d0
```

## Physically Reattaching a Device

Exactly how a missing device is reattached depends on the device in question. If the device is a network-attached drive, connectivity to the network should be restored. If the device is a USB device or other removable media, it should be reattached to the system. If the device is a local disk, a controller might have failed such that the device is no longer visible to the system. In this case, the controller should be replaced, at which point the disks will again be available. Other problems can exist and depend on the type of hardware and its configuration. If a drive fails and it is no longer visible to the system, the device should be treated as a damaged device. Follow the procedures in Replacing or Repairing a Damaged Device.

A pool might be `SUSPENDED` if device connectivity is compromised. A `SUSPENDED` pool remains in the wait state until the device issue is resolved. For example:

```
$ zpool status cybermen
pool: cybermen
state: SUSPENDED
status: One or more devices are unavailable in response to IO failures.
The pool is suspended.
action: Make sure the affected devices are connected, then run 'zpool clear' or
'fmadm repaired'.
Run 'zpool status -v' to see device specific details.
see: http://support.oracle.com/msg/ZFS-8000-HC
scan: none requested
config:

NAME        STATE     READ WRITE CKSUM
cybermen    UNAVAIL      0    16     0
c8t3d0      UNAVAIL      0     0     0
c8t1d0      UNAVAIL      0     0     0
```

After device connectivity is restored, clear the pool or device errors.

```
$ zpool clear cybermen
$ fmadm repaired zfs://pool=name/vdev=guid
```

## Notifying ZFS of Device Availability

After a device is reattached to the system, ZFS might or might not automatically detect its availability. If the pool was previously `UNAVAIL` or `SUSPENDED`, or the system was rebooted as part of the `attach` procedure, then ZFS automatically rescans all devices when it tries to open the pool. If the pool was degraded and the device was replaced while the system was running, you must notify ZFS that the device is now available and ready to be reopened by using the `zpool online` command. For example:

```
$ zpool online system1 c0t1d0
```

For more information about bringing devices online, see Taking Devices in a Storage Pool Offline or Returning Online.

# Replacing or Repairing a Damaged Device

This section describes how to determine device failure types, clear transient errors, and replacing a device.

## Determining the Type of Device Failure

The term *damaged device* is rather vague and can describe a number of possible situations:

- **Bit rot** – Over time, random events such as magnetic influences and cosmic rays can cause bits stored on disk to flip. These events are relatively rare but common enough to cause potential data corruption in large or long-running systems.
- **Misdirected reads or writes** – Firmware bugs or hardware faults can cause reads or writes of entire blocks to reference the incorrect location on disk. These errors are typically transient, though a large number of them might indicate a faulty drive.
- **Administrator error** – Administrators can unknowingly overwrite portions of a disk with bad data (such as copying `/dev/zero` over portions of the disk) that cause permanent corruption on disk. These errors are always transient.
- **Temporary outage**– A disk might become unavailable for a period of time, causing I/Os to fail. This situation is typically associated with network-attached devices, though local disks can experience temporary outages as well. These errors might or might not be transient.
- **Bad or flaky hardware** – This situation is a catch-all for the various problems that faulty hardware exhibits, including consistent I/O errors, faulty transports causing random corruption, or any number of failures. These errors are typically permanent.
- **Offline device** – If a device is offline, it is assumed that the administrator placed the device in this state because it is faulty. The administrator who placed the device in this state can determine if this assumption is accurate.

Determining exactly what is wrong with a device can be a difficult process. The first step is to examine the error counts in the `zpool status` output. For example:

```
$ zpool status -v system1
pool: system1
state: ONLINE
status: One or more devices has experienced an error resulting in data
corruption.  Applications may be affected.
action: Restore the file in question if possible. Otherwise restore the
entire pool from backup.
see: http://support.oracle.com/msg/ZFS-8000-8A
config:

NAME           STATE     READ WRITE CKSUM
system1        ONLINE       2     0     0
   c8t0d0      ONLINE       0     0     0
   c8t0d0      ONLINE       2     0     0

errors: Permanent errors have been detected in the following files:

/system1/file.1
```

The errors are divided into I/O errors and checksum errors, both of which might indicate the possible failure type. Typical operation predicts a very small number of errors (just a few over long periods of time). If you are seeing a large number of errors, then this situation probably indicates impending or complete device failure. However, an administrator error can also result in large error counts. The other source of information is the `syslog` system log. If the log shows a large number of SCSI or Fibre Channel driver messages, then this situation probably indicates serious hardware problems. If no `syslog` messages are generated, then the damage is likely transient.

The goal is to answer the following question:

*Is another error likely to occur on this device?*

Errors that happen only once are considered *transient* and do not indicate potential failure. Errors that are persistent or severe enough to indicate potential hardware failure are considered *fatal*. The act of determining the type of error is beyond the scope of any automated software currently available with ZFS, and so much must be done manually by you, the administrator. After determination is made, the appropriate action can be taken. Either clear the transient errors or replace the device due to fatal errors. These repair procedures are described in the next sections.

Even if the device errors are considered transient, they still might have caused uncorrectable data errors within the pool. These errors require special repair procedures, even if the underlying device is deemed healthy or otherwise repaired. For more information about repairing data errors, see Repairing Corrupted ZFS Data.

## Clearing Transient or Persistent Device Errors

If the device errors are deemed transient, in that they are unlikely to affect the future health of the device, they can be safely cleared to indicate that no fatal error occurred. To clear error counters for RAID-Z or mirrored devices, use the `zpool clear` command. For example:

```
$ zpool clear system1 c1t1d0
```

This syntax clears any device errors and clears any data error counts associated with the device.

To clear all errors associated with the virtual devices in a pool, and to clear any data error counts associated with the pool, use the following syntax:

```
$ zpool clear system1
```

For more information about clearing pool errors, see Clearing Storage Pool Device Errors.

Transient device errors are most likely cleared by using the `zpool clear` command. If a device has failed, then see the next section about replacing a device. If a redundant device was accidentally overwritten or was UNAVAIL for a long period of time, then this error might need to be resolved by using the `fmadm repaired` command as directed in the `zpool status` output. For example:

```
$ zpool status -v pond
pool: pond
state: DEGRADED
status: One or more devices are unavailable in response to persistent errors.
Sufficient replicas exist for the pool to continue functioning in a
degraded state.
action: Determine if the device needs to be replaced, and clear the errors
using 'zpool clear' or 'fmadm repaired', or replace the device
with 'zpool replace'.
scan: scrub repaired 0 in 0h0m with 0 errors on Wed Jun 20 15:38:08 2012
config:

NAME                    STATE     READ WRITE CKSUM
pond                    DEGRADED     0     0     0
mirror-0                DEGRADED     0     0     0
c0t5000C500335F95E3d0   ONLINE       0     0     0
c0t5000C500335F907Fd0   UNAVAIL      0     0     0
mirror-1                ONLINE       0     0     0
c0t5000C500335BD117d0   ONLINE       0     0     0
c0t5000C500335DC60Fd0   ONLINE       0     0     0
```

```
device details:

c0t5000C500335F907Fd0    UNAVAIL          cannot open
status: ZFS detected errors on this device.
The device was missing.
see: http://support.oracle.com/msg/ZFS-8000-LR for recovery


errors: No known data errors
```

# Replacing a Device in a ZFS Storage Pool

If device damage is permanent or future permanent damage is likely, the device must be replaced. Whether the device can be replaced depends on the configuration.

- Determining If a Device Can Be Replaced.
- Devices That Cannot be Replaced.
- Replacing a Device in a ZFS Storage Pool.
- Viewing Resilvering Status.

## Determining If a Device Can Be Replaced

If the device to be replaced is part of a redundant configuration, sufficient replicas from which to retrieve good data must exist. For example, if two disks in a four-way mirror are `UNAVAIL`, then either disk can be replaced because healthy replicas are available. However, if two disks in a four-way RAID-Z (`raidz1`) virtual device are `UNAVAIL`, then neither disk can be replaced because insufficient replicas from which to retrieve data exist. If the device is damaged but otherwise online, it can be replaced as long as the pool is not in the `UNAVAIL` state. However, any corrupted data on the device is copied to the new device, unless sufficient replicas with good data exist.

In the following configuration, the `c1t1d0` disk can be replaced, and any data in the pool is copied from the healthy replica, `c1t0d0`:

```
    mirror            DEGRADED
c1t0d0              ONLINE
c1t1d0              UNAVAIL
```

The `c1t0d0` disk can also be replaced, though no self-healing of data can take place because no good replica is available.

In the following configuration, neither `UNAVAIL` disk can be replaced. The `ONLINE` disks cannot be replaced either because the pool itself is `UNAVAIL`.

```
    raidz1              UNAVAIL
c1t0d0               ONLINE
c2t0d0               UNAVAIL
c3t0d0               UNAVAIL
c4t0d0               ONLINE
```

In the following configuration, either top-level disk can be replaced, though any bad data present on the disk is copied to the new disk.

```
c1t0d0         ONLINE
c1t1d0         ONLINE
```

If either disk is `UNAVAIL`, then no replacement can be performed because the pool itself is `UNAVAIL`.

## Devices That Cannot be Replaced

If the loss of a device causes the pool to become `UNAVAIL` or the device contains too many data errors in a non-redundant configuration, then the device cannot be safely replaced. Without sufficient redundancy, no good data with which to heal the damaged device exists. In this case, the only option is to destroy the pool and re-create the configuration, and then to restore your data from a backup copy.

For more information about restoring an entire pool, see Repairing ZFS Storage Pool-Wide Damage.

## Replacing a Device in a ZFS Storage Pool

After you have determined that a device can be replaced, use the `zpool replace` command to replace the device. If you are replacing the damaged device with different device, use syntax similar to the following:

```
$ zpool replace system1 c1t1d0 c2t0d0
```

This command migrates data to the new device from the damaged device or from other devices in the pool if it is in a redundant configuration. When the command is finished, it detaches the damaged device from the configuration, at which point the device can be removed from the system. If you have already removed the device and replaced it with a new device in the same location, use the single device form of the command. For example:

```
$ zpool replace system1 c1t1d0
```

This command takes an unformatted disk, formats it appropriately, and then resilvers data from the rest of the configuration.

For more information about the `zpool replace` command, see Replacing Devices in a Storage Pool.

**Example 11-1 Replacing a SATA Disk in a ZFS Storage Pool**

The following example shows how to replace a device (`c1t3d0`) in a mirrored storage pool `system1` on a system with SATA devices. To replace the disk `c1t3d0` with a new disk at the same location (`c1t3d0`), then you must unconfigure the disk before you attempt to replace it. If the disk to be replaced is not a SATA disk, then see Replacing Devices in a Storage Pool.

The basic steps follow:

- Take offline the disk (`c1t3d0`)to be replaced. You cannot unconfigure a SATA disk that is currently being used.
- Use the `cfgadm` command to identify the SATA disk (`c1t3d0`) to be unconfigured and unconfigure it. The pool will be degraded with the offline disk in this mirrored configuration, but the pool will continue to be available.
- Physically replace the disk (`c1t3d0`). Ensure that the blue `Ready to Remove` LED is illuminated before you physically remove the `UNAVAIL` drive, if available.
- Reconfigure the SATA disk (`c1t3d0`).
- Bring the new disk (`c1t3d0`) online.
- Run the `zpool replace` command to replace the disk (`c1t3d0`).

> **Note:**
>
> If you had previously set the pool property `autoreplace` to `on`, then any new device, found in the same physical location as a device that previously belonged to the pool is automatically formatted and replaced without using the `zpool replace` command. This feature might not be supported on all hardware.

- If a failed disk is automatically replaced with a hot spare, you might need to detach the hot spare after the failed disk is replaced. For example, if `c2t4d0` is still an active hot spare after the failed disk is replaced, then detach it.

  ```
  $ zpool detach system1 c2t4d0
  ```

- If FMA is reporting the failed device, then you should clear the device failure.

  ```
  $ fmadm faulty
  $ fmadm repaired zfs://pool=name/vdev=guid
  ```

The following example walks through the steps to replace a disk in a ZFS storage pool.

```
$ zpool offline system1 c1t3d0
$ cfgadm | grep c1t3d0
sata1/3::dsk/c1t3d0            disk         connected    configured   ok
$ cfgadm -c unconfigure sata1/3
Unconfigure the device at: /devices/pci@0,0/pci1022,7458@2/pci11ab,11ab@1:3
This operation will suspend activity on the SATA device
Continue (yes/no)? yes
$ cfgadm | grep sata1/3
sata1/3                        disk         connected    unconfigured ok
<Physically replace the failed disk c1t3d0>
$ cfgadm -c configure sata1/3
$ cfgadm | grep sata1/3
sata1/3::dsk/c1t3d0            disk         connected    configured   ok
$ zpool online system1 c1t3d0
$ zpool replace system1 c1t3d0
# zpool status system1
pool: system1
state: ONLINE
scrub: resilver completed after 0h0m with 0 errors on Tue Feb  2 13:17:32 2010
config:

NAME           STATE     READ WRITE CKSUM
system1        ONLINE       0     0     0
   mirror-0    ONLINE       0     0     0
      c0t1d0   ONLINE       0     0     0
      c1t1d0   ONLINE       0     0     0
   mirror-1    ONLINE       0     0     0
      c0t2d0   ONLINE       0     0     0
      c1t2d0   ONLINE       0     0     0
   mirror-2    ONLINE       0     0     0
      c0t3d0   ONLINE       0     0     0
      c1t3d0   ONLINE       0     0     0

errors: No known data errors
```

Note that the preceding `zpool output` might show both the new and old disks under a *replacing* heading. For example:

```
replacing   DEGRADED     0     0    0
c1t3d0s0/o  FAULTED      0     0    0
c1t3d0      ONLINE       0     0    0
```

This text means that the replacement process is in progress and the new disk is being resilvered.

If you are going to replace a disk (`c1t3d0`) with another disk (`c4t3d0`), then you only need to run the `zpool replace` command. For example:

```
$ zpool replace system1 c1t3d0 c4t3d0
$ zpool status
pool: system1
state: DEGRADED
scrub: resilver completed after 0h0m with 0 errors on Tue Feb  2 13:35:41 2010
config:

NAME           STATE     READ WRITE CKSUM
system1        DEGRADED     0     0     0
   mirror-0    ONLINE       0     0     0
      c0t1d0   ONLINE       0     0     0
      c1t1d0   ONLINE       0     0     0
   mirror-1    ONLINE       0     0     0
      c0t2d0   ONLINE       0     0     0
      c1t2d0   ONLINE       0     0     0
   mirror-2    DEGRADED     0     0     0
      c0t3d0   ONLINE       0     0     0
   replacing   DEGRADED     0     0     0
      c1t3d0   OFFLINE      0     0     0
      c4t3d0   ONLINE       0     0     0

errors: No known data errors
```

You might need to run the `zpool status` command several times until the disk replacement is completed.

```
$ zpool status system1
pool: system1
state: ONLINE
scrub: resilver completed after 0h0m with 0 errors on Tue Feb  2 13:35:41 2010
config:

NAME           STATE     READ WRITE CKSUM
system1        ONLINE       0     0     0
   mirror-0    ONLINE       0     0     0
      c0t1d0   ONLINE       0     0     0
      c1t1d0   ONLINE       0     0     0
   mirror-1    ONLINE       0     0     0
      c0t2d0   ONLINE       0     0     0
      c1t2d0   ONLINE       0     0     0
   mirror-2    ONLINE       0     0     0
      c0t3d0   ONLINE       0     0     0
      c4t3d0   ONLINE       0     0     0
```

**Example 11-2 Replacing a Failed Log Device**

ZFS identifies intent log failures in the `zpool status` command output. Fault Management Architecture (FMA) reports these errors as well. Both ZFS and FMA describe how to recover from an intent log failure.

The following example shows how to recover from a failed log device (`c0t5d0`) in the storage pool (`storpool`). The basic steps follow:

- Review the `zpool status -x` output and FMA diagnostic message, described in *ZFS intent log read failure (Doc ID 1021625.1)* in https://support.oracle.com/ .

- Physically replace the failed log device.
- Bring the new log device online.
- Clear the pool's error condition.
- Clear the FMA error.

For example, if the system shuts down abruptly before synchronous write operations are committed to a pool with a separate log device, you see messages similar to the following:

```
$ zpool status -x
pool: storpool
state: FAULTED
status: One or more of the intent logs could not be read.
Waiting for administrator intervention to fix the faulted pool.
action: Either restore the affected device(s) and run 'zpool online',
or ignore the intent log records by running 'zpool clear'.
scrub: none requested
config:

NAME           STATE     READ WRITE CKSUM
storpool       FAULTED      0     0     0 bad intent log
   mirror-0    ONLINE       0     0     0
      c0t1d0   ONLINE       0     0     0
      c0t4d0   ONLINE       0     0     0
   logs        FAULTED      0     0     0 bad intent log
      c0t5d0   UNAVAIL      0     0     0 cannot open
<Physically replace the failed log device>
$ zpool online storpool c0t5d0
$ zpool clear storpool
$ fmadm faulty
$ fmadm repair zfs://pool=name/vdev=guid
```

You can resolve the log device failure in the following ways:

- Replace or recover the log device. In this example, the log device is `c0t5d0`.
- Bring the log device back online.

  ```
  $ zpool online storpool c0t5d0
  ```

- Reset the failed log device error condition.

  ```
  $ zpool clear storpool
  ```

To recover from this error without replacing the failed log device, you can clear the error with the `zpool clear` command. In this scenario, the pool will operate in a degraded mode and the log records will be written to the main pool until the separate log device is replaced.

Consider using mirrored log devices to avoid the log device failure scenario.

## Viewing Resilvering Status

The process of replacing a device can take an extended period of time, depending on the size of the device and the amount of data in the pool. The process of moving data from one device to another device is known as *resilvering* and can be monitored by using the `zpool status` command.

The following `zpool status` resilver status messages are provided:

- Resilver in-progress report. For example:

```
    scan: resilver in progress since Mon Jun  7 09:17:27 2010
    13.3G scanned
    13.3G resilvered at 18.5M/s, 82.34% done, 0h2m to go
```

- Resilver completion message. For example:

```
    resilvered 16.2G in 0h16m with 0 errors on Mon Jun  7 09:34:21 2010
```

Resilver completion messages persist across system reboots.

Traditional file systems resilver data at the block level. Because ZFS eliminates the artificial layering of the volume manager, it can perform resilvering in a much more powerful and controlled manner. The two main advantages of this feature are as follows:

- ZFS only resilvers the minimum amount of necessary data. In the case of a short outage (as opposed to a complete device replacement), the entire disk can be resilvered in a matter of minutes or seconds. When an entire disk is replaced, the resilvering process takes time proportional to the amount of data used on disk. Replacing a 500GB disk can take seconds if a pool has only a few gigabytes of used disk space.
- If the system loses power or is rebooted, the resilvering process resumes exactly where it left off, without any need for manual intervention.

To view the resilvering process, use the `zpool status` command. For example:

```
$ zpool status system1
pool: system1
state: ONLINE
status: One or more devices is currently being resilvered.  The pool will
continue to function, possibly in a degraded state.
action: Wait for the resilver to complete.
scan: resilver in progress since Mon Jun  7 10:49:20 2010
54.6M scanned54.5M resilvered at 5.46M/s, 24.64% done, 0h0m to go

config:

NAME             STATE     READ WRITE CKSUM
system1          ONLINE       0     0     0
   mirror-0      ONLINE       0     0     0
   replacing-0   ONLINE       0     0     0
      c1t0d0     ONLINE       0     0     0
      c2t0d0     ONLINE       0     0     0  (resilvering)
      c1t1d0     ONLINE       0     0     0
```

In this example, the disk `c1t0d0` is being replaced by `c2t0d0`. This event is observed in the status output by the presence of the `replacing` virtual device in the configuration. This device is not real, nor is it possible for you to create a pool by using it. The purpose of this device is solely to display the resilvering progress and to identify which device is being replaced.

Note that any pool currently undergoing resilvering is placed in the `ONLINE` or `DEGRADED` state because the pool cannot provide the desired level of redundancy until the resilvering process is completed. Resilvering proceeds as fast as possible, though the I/O is always scheduled with a lower priority than user-requested I/O, to minimize impact on the system. After the resilvering is completed, the configuration reverts to the new, complete, configuration. For example:

```
$ zpool status system1
pool: system1
state: ONLINE
scrub: resilver completed after 0h1m with 0 errors on Tue Feb  2 13:54:30 2010
config:

NAME          STATE     READ WRITE CKSUM
system1       ONLINE       0     0     0
```

```
   mirror-0   ONLINE       0     0     0
      c2t0d0  ONLINE       0     0     0  377M resilvered
      c1t1d0  ONLINE       0     0     0

errors: No known data errors
```

The pool is once again `ONLINE`, and the original failed disk (`c1t0d0`) has been removed from the configuration.

## Changing Pool Devices

Do not try to change pool devices under an active pool.

Disks are identified both by their path and by their device ID, if available. On systems where device ID information is available, this identification method allows devices to be reconfigured without updating ZFS. Because device ID generation and management can vary by system, export the pool first before moving devices, such as moving a disk from one controller to another controller. A system event, such as a firmware update or other hardware change, might change the device IDs in your ZFS storage pool, which can cause the devices to become unavailable.

An additional problem is that if you attempt to change the devices underneath a pool and then you use the `zpool status` command as a non-root user, the previous device names could be displayed.

# Resolving Data Problems in a ZFS Storage Pool

Examples of data problems include the following:

- Pool or file system space is missing
- Transient I/O errors due to a bad disk or controller
- On-disk data corruption due to cosmic rays
- Driver bugs resulting in data being transferred to or from the wrong location
- A user overwriting portions of the physical device by accident

In some cases, these errors are transient, such as a random I/O error while the controller is having problems. In other cases, the damage is permanent, such as on-disk corruption. Even still, whether the damage is permanent does not necessarily indicate that the error is likely to occur again. For example, if you accidentally overwrite part of a disk, no type of hardware failure has occurred, and the device does not need to be replaced. Identifying the exact problem with a device is not an easy task and is covered in more detail in a later section.

## Resolving ZFS Space Issues

Review the following sections if you are unsure how ZFS reports file system and pool space accounting.

### ZFS File System Space Reporting

The `zpool list` and `zfs list` commands are better than the previous `df` and `du` commands for determining your available pool and file system space. With the legacy commands, you cannot easily discern between pool and file system space, nor do the legacy commands account for space that is consumed by descendant file systems or snapshots.

For example, the following root pool (rpool) has 5.46 GB allocated and 68.5 GB free.

```
$ zpool list rpool
NAME   SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
rpool   74G  5.46G  68.5G   7%  1.00x  ONLINE  -
```

If you compare the pool space accounting with the file system space accounting by reviewing the USED column of your individual file systems, you can see that the pool space that is reported in ALLOC is accounted for in the file systems' USED total. For example:

```
$ zfs list -r rpool
NAME                      USED  AVAIL  REFER  MOUNTPOINT
rpool                    5.41G  67.4G  74.5K  /rpool
rpool/ROOT               3.37G  67.4G    31K  legacy
rpool/ROOT/solaris       3.37G  67.4G  3.07G  /
rpool/ROOT/solaris/var    302M  67.4G   214M  /var
rpool/dump               1.01G  67.5G  1000M  -
rpool/export             97.5K  67.4G    32K  /rpool/export
rpool/export/home        65.5K  67.4G    32K  /rpool/export/home
rpool/export/home/admin  33.5K  67.4G  33.5K  /rpool/export/home/admin
rpool/swap               1.03G  67.5G  1.00G  -
```

## ZFS Storage Pool Space Reporting

The SIZE value that is reported by the zpool list command is generally the amount of physical disk space in the pool, but varies depending on the pool's redundancy level. See the examples below. The zfs list command lists the usable space that is available to file systems, which is disk space minus ZFS pool redundancy metadata overhead, if any.

The following ZFS dataset configurations are tracked as allocated space by the zfs list command but they are not tracked as allocated space in the zpool list output:

- ZFS file system quota
- ZFS file system reservation
- ZFS logical volume size

The following items describe how using different pool configurations, ZFS volumes and ZFS reservations can impact your consumed and available disk space. Depending upon your configuration, monitoring pool space should be tracked by using the steps listed below.

- **Non-redundant storage pool** – When a pool is created with one 136GB disk, the zpool list command reports SIZE and initial FREE values as 136 GB. The initial AVAIL space reported by the zfs list command is 134 GB, due to a small amount of pool metadata overhead. For example:

  ```
  $ zpool create system1 c0t6d0
  $ zpool list system1
  NAME      SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
  system1   136G  95.5K   136G     0%  1.00x  ONLINE  -
  $ zfs list system1
  NAME      USED  AVAIL  REFER  MOUNTPOINT
  system1    72K   134G    21K  /system1
  ```

- **Mirrored storage pool** – When a pool is created with two 136GB disks, zpool list command reports SIZE as 136 GB and initial FREE value as 136 GB. This reporting is referred to as the *deflated* space value. The initial AVAIL space reported by the zfs list command is 134 GB, due to a small amount of pool metadata overhead. For example:

  ```
  $ zpool create system1 mirror c0t6d0 c0t7d0
  $ zpool list system1
  ```

```
NAME      SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
system1   136G  95.5K   136G     0%  1.00x  ONLINE  -
$ zfs list system1
NAME      USED  AVAIL  REFER  MOUNTPOINT
system1    72K   134G    21K  /system1
```

- **RAID-Z storage pool** – When a `raidz2` pool is created with three 136GB disks, the `zpool list` commands reports `SIZE` as 408 GB and initial `FREE` value as 408 GB. This reporting is referred to as the *inflated* disk space value, which includes redundancy overhead, such as parity information. The initial `AVAIL` space reported by the `zfs list` command is 133 GB, due to the pool redundancy overhead. The space discrepancy between the `zpool list` and the `zfs list` output for a RAID-Z pool is because `zpool list` reports the inflated pool space.

```
$ zpool create system1 raidz2 c0t6d0 c0t7d0 c0t8d0
$ zpool list system1
NAME      SIZE  ALLOC   FREE    CAP  DEDUP  HEALTH  ALTROOT
system1   408G   286K   408G     0%  1.00x  ONLINE  -
$ zfs list system1
NAME      USED  AVAIL  REFER  MOUNTPOINT
system1  73.2K   133G  20.9K  /system1
```

- **NFS mounted file system space** – Neither the `zpool list` or the `zfs list` account for NFS mounted file system space. However, local data files can be hidden under a mounted NFS file system. If you are missing file system space, ensure that you do not have data files hidden under an NFS file system.
- **Using ZFS Volumes** – When a ZFS file system is created and pool space is consumed, you can view the file system space consumption by using the zpool list command. For example:

```
$ zpool create nova mirror c1t1d0 c2t1d0
$ zfs create nova/fs1
$ mkfile 10g /nova/fs1/file1_10g
$ zpool list nova
NAME  SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
nova   68G  10.0G  58.0G  14%  1.00x  ONLINE  -
$ zfs list -r nova
NAME       USED  AVAIL  REFER  MOUNTPOINT
nova      10.0G  56.9G    32K  /nova
nova/fs1  10.0G  56.9G  10.0G  /nova/fs1
```

If you create a 10GB ZFS volume, the space is not accounted for in the zpool list command. The space is accounted for in the zfs list command. If you are using ZFS volumes in your storage pools, monitor ZFS volume space consumption by using the zfs list command. For example:

```
$ zfs create -V 10g nova/vol1
$ zpool list nova
NAME  SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
nova   68G  10.0G  58.0G  14%  1.00x  ONLINE  -
$ zfs list -r nova
NAME        USED  AVAIL  REFER  MOUNTPOINT
nova       20.3G  46.6G    32K  /nova
nova/fs1   10.0G  46.6G  10.0G  /nova/fs1
nova/vol1  10.3G  56.9G    16K  -
```

Note in the above output that ZFS volume space is not tracked in the zpool list output so use the zfs list or the zfs list -o space command to identify space that is consumed by ZFS volumes.

In addition, because ZFS volumes act like raw devices, some amount of space for metadata is automatically reserved through the refreservation property, which causes volumes to consume slightly more space then the amount specified when the volume was created. Do not remove the refreservation on ZFS volumes or you risk running out of volume space.

- **Using ZFS Reservations** – If you create a file system with a reservation or add a reservation to an existing file system, reservations or refreservations are not tracked by the `zpool list` command.

  Identify space that is consumed by file system reservations by using the `zfs list -r` command to identify the increased USED space. For example:

```
$ zfs create -o reservation=10g nova/fs2
$ zpool list nova
NAME  SIZE  ALLOC   FREE  CAP  DEDUP  HEALTH  ALTROOT
nova   68G  10.0G  58.0G  14%  1.00x  ONLINE  -
$ zfs list -r nova
NAME        USED  AVAIL  REFER  MOUNTPOINT
nova       30.3G  36.6G    33K  /nova
nova/fs1   10.0G  36.6G  10.0G  /nova/fs1
nova/fs2     31K  46.6G    31K  /nova/fs2
nova/vol1  10.3G  46.9G    16K  -
```

  If you create a file system with a `refreservation`, it can be identified by using the zfs list -r command. For example:

```
$ zfs create -o refreservation=10g nova/fs3
$ zfs list -r nova
NAME        USED  AVAIL  REFER  MOUNTPOINT
nova       40.3G  26.6G    35K  /nova
nova/fs1   10.0G  26.6G  10.0G  /nova/fs1
nova/fs2     31K  36.6G    31K  /nova/fs2
nova/fs3     10G  36.6G    31K  /nova/fs3
nova/vol1  10.3G  36.9G    16K  -
```

  Use the following command to identify all existing reservations to account for total USED space.

```
$ zfs get -r reserv,refreserv nova
NAME       PROPERTY        VALUE  SOURCE
nova       reservation     none   default
nova       refreservation  none   default
nova/fs1   reservation     none   default
nova/fs1   refreservation  none   default
nova/fs2   reservation     10G    local
nova/fs2   refreservation  none   default
nova/fs3   reservation     none   default
nova/fs3   refreservation  10G    local
nova/vol1  reservation     none   default
nova/vol1  refreservation  10.3G  local
```

# Checking ZFS File System Integrity

No `fsck` utility equivalent exists for ZFS. This utility has traditionally served two purposes, those of file system repair and file system validation.

## File System Repair

With traditional file systems, the way in which data is written is inherently vulnerable to unexpected failure causing file system inconsistencies. Because a traditional file system is not

transactional, unreferenced blocks, bad link counts, or other inconsistent file system structures are possible. The addition of journaling does solve some of these problems, but can introduce additional problems when the log cannot be rolled back. The only way for inconsistent data to exist on disk in a ZFS configuration is through hardware failure (in which case the pool should have been redundant) or when a bug exists in the ZFS software.

The `fsck` utility repairs known problems specific to UFS file systems. Most ZFS storage pool problems are generally related to failing hardware or power failures. Many problems can be avoided by using redundant pools. If your pool is damaged due to failing hardware or a power outage, see Repairing ZFS Storage Pool-Wide Damage.

If your pool is not redundant, the risk that file system corruption can render some or all of your data inaccessible is always present.

## File System Validation

In addition to performing file system repair, the `fsck` utility validates that the data on disk has no problems. Traditionally, this task requires unmounting the file system and running the `fsck` utility, possibly taking the system to single-user mode in the process. This scenario results in downtime that is proportional to the size of the file system being checked. Instead of requiring an explicit utility to perform the necessary checking, ZFS provides a mechanism to perform routine checking of all inconsistencies. This feature, known as *scrubbing*, is commonly used in memory and other systems as a method of detecting and preventing errors before they result in a hardware or software failure.

## Controlling ZFS Data Scrubbing

Whenever ZFS encounters an error, either through scrubbing or when accessing a file on demand, the error is logged internally so that you can obtain a quick overview of all known errors within the pool.

### Explicit ZFS Data Scrubbing

The simplest way to check data integrity is to initiate an explicit scrubbing of all data within the pool. This operation traverses all the data in the pool once and verifies that all blocks can be read. Scrubbing proceeds as fast as the devices allow, though the priority of any I/O remains below that of normal operations. This operation might negatively impact performance, though the pool's data should remain usable and nearly as responsive while the scrubbing occurs. To initiate an explicit scrub, use the `zpool scrub` command. For example:

```
$ zpool scrub system1
```

The status of the current scrubbing operation can be displayed by using the `zpool status` command. For example:

```
$ zpool status -v system1
pool: system1
state: ONLINE
scan: scrub in progress since Mon Jun  7 12:07:52 2010
201M scanned out of 222M at 9.55M/s, 0h0m to go
0 repaired, 90.44% done
config:

NAME          STATE     READ WRITE CKSUM
system1       ONLINE       0     0     0
   mirror-0   ONLINE       0     0     0
      c1t0d0  ONLINE       0     0     0
      c1t1d0  ONLINE       0     0     0
```

```
errors: No known data errors
```

Only one active scrubbing operation per pool can occur at one time.

You can stop a scrubbing operation that is in progress by using the `-s` option. For example:

```
$ zpool scrub -s system1
```

In most cases, a scrubbing operation to ensure data integrity should continue to completion. Stop a scrubbing operation at your own discretion if system performance is impacted by the operation.

Performing routine scrubbing guarantees continuous I/O to all disks on the system. Routine scrubbing has the side effect of preventing power management from placing idle disks in low-power mode. If the system is generally performing I/O all the time, or if power consumption is not a concern, then this issue can safely be ignored. If the system is largely idle, and you want to conserve power to the disks, you should consider using a `cron` scheduled explicit scrub rather than background scrubbing. This will still perform complete scrubs of data, though it will only generate a large amount of I/O until the scrubbing is finished, at which point the disks can be power managed as normal. The downside (besides increased I/O) is that there will be large periods of time when no scrubbing is being done at all, potentially increasing the risk of corruption during those periods.

For more information about interpreting `zpool status` output, see Querying ZFS Storage Pool Status.

## Scheduled Data Scrubbing

Data inconsistencies can occur over time. Scrubbing the data regularly helps to find these inconsistencies and resolve them early. Thus, regular scrubbing ensures data availability.

In this release, automatic scrubbing is added as a preventative maintenance tool. Automatic or scheduled data scrubbing is now part of routine operations. The feature is enabled by default upon installation. Two ZFS properties are associated with scheduled scrubbing:

- `scrubinterval` determines the time interval between automatic scrubbing. The value is specified together with the following units of time: `s`, `h`, `d`, `w`, `m`, or `y`. These correspond to second, hour, day, week, month, or year, respectively. A week can also be specified as 7 days, a month as 30 days, and a year as 365 days. By default, the time interval is set to 30 days.

  > **Note:**
  >
  > Setting the interval to `manual` disables automatic scrubbing.

  When you set the time interval, you must use only a single time unit, not a combination of units.

  – Incorrect

  ```
  $ zpool set scrubinterval=1w3d
  ```

  – Correct

  ```
  $ zpool set scrubinterval=10d
  ```

- `lastscrub` is a read-only property that specifies the start time of the last scrub that either completed successfully or was canceled. The system uses this value to calculate the next scrubbing based on the specified interval.

You can manually start the scrub operation outside of the scheduled time. The operation would fail if a scheduled scrub is already in progress.

Just like with a manual scrub, you can cancel an ongoing scheduled scrub. In this case, a scrub operation will be scheduled to run at the next period as specified by the interval and calculated from the start time of the canceled scrub. To cancel an ongoing scrub operation, you use the following command:

```
$ zpool scrub -s
```

A scheduled scrub runs only when no other scrub or a resilver operation is in progress. When you initiate a resilver operation, an ongoing scheduled scrub is immediately canceled, and will restart after the resliver completes.

### ZFS Data Scrubbing and Resilvering

When a device is replaced, a resilvering operation is initiated to move data from the good copies to the new device. This action is a form of disk scrubbing. Therefore, only one such action can occur at a given time in the pool. If a scrubbing operation is in progress, a resilvering operation suspends the current scrubbing and restarts it after the resilvering is completed.

For more information about resilvering, see Viewing Resilvering Status.

## Repairing Corrupted ZFS Data

Data corruption occurs when one or more device errors (indicating one or more missing or damaged devices) affects a top-level virtual device. For example, one half of a mirror can experience thousands of device errors without ever causing data corruption. If an error is encountered on the other side of the mirror in the exact same location, corrupted data is the result.

Data corruption is always permanent and requires special consideration during repair. Even if the underlying devices are repaired or replaced, the original data is lost forever. Most often, this scenario requires restoring data from backups. Data errors are recorded as they are encountered, and they can be controlled through routine pool scrubbing as explained in the following section. When a corrupted block is removed, the next scrubbing pass recognizes that the corruption is no longer present and removes any trace of the error from the system.

The following sections describe how to identify the type of data corruption and how to repair the data, if possible.

- Identifying the Type of Data Corruption.
- Repairing a Corrupted File or Directory.
- Repairing ZFS Storage Pool-Wide Damage.

ZFS uses checksums, redundancy, and self-healing data to minimize the risk of data corruption. Nonetheless, data corruption can occur if a pool isn't redundant, if corruption occurred while a pool was degraded, or an unlikely series of events conspired to corrupt multiple copies of a piece of data. Regardless of the source, the result is the same: The data is corrupted and therefore no longer accessible. The action taken depends on the type of data being corrupted and its relative value. Two basic types of data can be corrupted:

- Pool metadata – ZFS requires a certain amount of data to be parsed to open a pool and access datasets. If this data is corrupted, the entire pool or portions of the dataset hierarchy will become unavailable.
- Object data – In this case, the corruption is within a specific file or directory. This problem might result in a portion of the file or directory being inaccessible, or this problem might cause the object to be broken altogether.

Data is verified during normal operations as well as through a scrubbing. For information about how to verify the integrity of pool data, see Checking ZFS File System Integrity.

## Identifying the Type of Data Corruption

By default, the `zpool status` command shows only that corruption has occurred, but not where this corruption occurred. For example:

```
$ zpool status system1
pool: system1
state: ONLINE
status: One or more devices has experienced an error resulting in data
corruption.  Applications may be affected.
action: Restore the file in question if possible. Otherwise restore the
entire pool from backup.
see: http://support.oracle.com/msg/ZFS-8000-8A
config:

NAME                          STATE     READ WRITE CKSUM
   system1                    ONLINE       4     0     0
      c0t5000C500335E106Bd0   ONLINE       0     0     0
      c0t5000C500335FC3E7d0   ONLINE       4     0     0


errors: 2 data errors, use '-v' for a list
```

Each error indicates only that an error occurred at a given point in time. Each error is not necessarily still present on the system. Under normal circumstances, this is the case. Certain temporary outages might result in data corruption that is automatically repaired after the outage ends. A complete scrub of the pool is guaranteed to examine every active block in the pool, so the error log is reset whenever a scrub finishes. If you determine that the errors are no longer present, and you don't want to wait for a scrub to complete, reset all errors in the pool by using the `zpool online` command.

If the data corruption is in pool-wide metadata, the output is slightly different. For example:

```
$ zpool status -v morpheus
pool: morpheus
id: 13289416187275223932
state: UNAVAIL
status: The pool metadata is corrupted.
action: The pool cannot be imported due to damaged devices or data.
see: http://support.oracle.com/msg/ZFS-8000-72
config:

morpheus  FAULTED   corrupted data
c1t10d0   ONLINE
```

In the case of pool-wide corruption, the pool is placed into the `FAULTED` state because the pool cannot provide the required redundancy level.

# Repairing a Corrupted File or Directory

If a file or directory is corrupted, the system might still function, depending on the type of corruption. Any damage is effectively unrecoverable if no good copies of the data exist on the system. If the data is valuable, you must restore the affected data from backup. Even so, you might be able to recover from this corruption without restoring the entire pool.

If the damage is within a file data block, then the file can be safely removed, thereby clearing the error from the system. Use the `zpool status -v` command to display a list of file names with persistent errors. For example:

```
$ zpool status system1 -v
pool: system1
state: ONLINE
status: One or more devices has experienced an error resulting in data
corruption.  Applications may be affected.
action: Restore the file in question if possible. Otherwise restore the
entire pool from backup.
see: http://support.oracle.com/msg/ZFS-8000-8A
config:

NAME                          STATE     READ WRITE CKSUM
   system1                    ONLINE       4     0     0
      c0t5000C500335E106Bd0   ONLINE       0     0     0
      c0t5000C500335FC3E7d0   ONLINE       4     0     0

errors: Permanent errors have been detected in the following files:
/system1/file.1
/system1/file.2
```

The list of file names with persistent errors might be described as follows:

- If the full path to the file is found and the dataset is mounted, the full path to the file is displayed. For example:

  ```
  /path1/a.txt
  ```

- If the full path to the file is found, but the dataset is not mounted, then the dataset name with no preceding slash (/), followed by the path within the dataset to the file, is displayed. For example:

  ```
  path1/documents/e.txt
  ```

- If the object number to a file path cannot be successfully translated, either due to an error or because the object does not have a real file path associated with it, as is the case for a `dnode_t`, then the dataset name followed by the object's number is displayed. For example:

  ```
  path1/dnode:<0x0>
  ```

- If an object in the metaobject set (MOS) is corrupted, then a special tag of `<metadata>`, followed by the object number, is displayed.

You can attempt to resolve more minor data corruption by using scrubbing the pool and clearing the pool errors in multiple iterations. If the first scrub and clear iteration does not resolve the corrupted files, run them again. For example:

```
$ zpool scrub system1
$ zpool clear system1
```

If the corruption is within a directory or a file's metadata, the only choice is to move the file elsewhere. You can safely move any file or directory to a less convenient location, allowing the original object to be restored in its place.

If a damaged file system has corrupted data with multiple block references, such as snapshots, the `zpool status -v` command cannot display **all** corrupted data paths. The current `zpool status` reporting of corrupted data is limited by the amount of metadata corruption and if any blocks have been reused after the `zpool status` command is executed. Deduplicated blocks makes reporting all corrupted data even more complicated.

If you have corrupted data and the `zpool status -v` command identifies that snapshot data is impacted, then considering running the following command to identify additional corrupted paths:

```
$ find mount-point -inum $inode -print
$ find mount-point/.zfs/snapshot -inum $inode -print
```

The first command searches for the inode number of the reported corrupted data in the specified file system and all its snapshots. The second command searches for snapshots with the same inode number.

# Repairing ZFS Storage Pool-Wide Damage

If the damage is in pool metadata and that damage prevents the pool from being opened or imported, then the following options are available to you:

- You can attempt to recover the pool by using the `zpool clear -F` command or the `zpool import -F` command. These commands attempt to roll back the last few pool transactions to an operational state. You can use the `zpool status` command to review a damaged pool and the recommended recovery steps. For example:

  ```
  $ zpool status
  pool: storpool
  state: UNAVAIL
  status: The pool metadata is corrupted and the pool cannot be opened.
  action: Recovery is possible, but will result in some data loss.
  Returning the pool to its state as of Fri Jun 29 17:22:49 2012
  should correct the problem.  Approximately 5 seconds of data
  must be discarded, irreversibly.  Recovery can be attempted
  by executing 'zpool clear -F tpool'.  A scrub of the pool
  is strongly recommended after recovery.
  see: http://support.oracle.com/msg/ZFS-8000-72
  scrub: none requested
  config:

  NAME         STATE     READ WRITE CKSUM
  storpool     UNAVAIL      0     0     1  corrupted data
     c1t1d0    ONLINE       0     0     2
     c1t3d0    ONLINE       0     0     4
  ```

  The recovery process as described in the preceding output is to use the following command:

  ```
  $ zpool clear -F storpool
  ```

  If you attempt to import a damaged storage pool, you will see messages similar to the following:

  ```
  $ zpool import storpool
  cannot import 'storpool': I/O error
  ```

```
Recovery is possible, but will result in some data loss.
Returning the pool to its state as of Fri Jun 29 17:22:49 2012
should correct the problem.  Approximately 5 seconds of data
must be discarded, irreversibly.  Recovery can be attempted
by executing 'zpool import -F storpool'.  A scrub of the pool
is strongly recommended after recovery.
```

The recovery process as described in the preceding output is to use the following command:

```
$ zpool import -F storpool
Pool storpool returned to its state as of Fri Jun 29 17:22:49 2012.
Discarded approximately 5 seconds of transactions
```

If the damaged pool is in the `zpool.cache` file, the problem is discovered when the system is booted, and the damaged pool is reported in the `zpool status` command. If the pool isn't in the `zpool.cache` file, it won't successfully import or open and you will see the damaged pool messages when you attempt to import the pool.

- You can import a damaged pool in read-only mode. This method enables you to import the pool so that you can access the data. For example:

  ```
  $ zpool import -o readonly=on storpool
  ```

  For more information about importing a pool read-only, see Importing a Pool in Read-Only Mode.

- You can import a pool with a missing log device by using the `zpool import -m` command. For more information, see Importing a Pool With a Missing Log Device.

- If the pool cannot be recovered by either pool recovery method, you must restore the pool and all its data from a backup copy. The mechanism you use varies widely depending on the pool configuration and backup strategy. First, save the configuration as displayed by the `zpool status` command so that you can re-create it after the pool is destroyed. Then, use the `zpool destroy -f` command to destroy the pool.

  Also, keep a file describing the layout of the datasets and the various locally set properties somewhere safe, as this information will become inaccessible if the pool is ever rendered inaccessible. With the pool configuration and dataset layout, you can reconstruct your complete configuration after destroying the pool. The data can then be populated by using whatever backup or restoration strategy you use.

# Repairing a Damaged ZFS Configuration

ZFS maintains a cache of active pools and their configuration in the root file system. If this cache file is corrupted or somehow becomes out of sync with configuration information that is stored on disk, the pool can no longer be opened. ZFS tries to avoid this situation, though arbitrary corruption is always possible given the qualities of the underlying storage. This situation typically results in a pool disappearing from the system when it should otherwise be available. This situation can also manifest as a partial configuration that is missing an unknown number of top-level virtual devices. In either case, the configuration can be recovered by exporting the pool (if it is visible at all) and re-importing it.

For information about importing and exporting pools, see Migrating ZFS Storage Pools.

# Repairing an Unbootable System

ZFS is designed to be robust and stable despite errors. Even so, software bugs or certain unexpected problems might cause the system to panic when a pool is accessed. As part of the

boot process, each pool must be opened, which means that such failures will cause a system to enter into a panic-reboot loop. To recover from this situation, ZFS must be informed not to look for any pools on startup.

ZFS maintains an internal cache of available pools and their configurations in `/etc/zfs/zpool.cache`. The location and contents of this file are private and are subject to change. If the system becomes unbootable, boot to the milestone `none` by using the `-m milestone=none` boot option. After the system is up, remount your root file system as writable and then rename or move the `/etc/zfs/zpool.cache` file to another location. These actions cause ZFS to forget that any pools exist on the system, preventing it from trying to access the unhealthy pool causing the problem. You can then proceed to a normal system state by issuing the `svcadm milestone all` command. You can use a similar process when booting from an alternate root to perform repairs.

After the system is up, you can attempt to import the pool by using the `zpool import` command. However, doing so will likely cause the same error that occurred during boot, because the command uses the same mechanism to access pools. If multiple pools exist on the system, do the following:

- Rename or move the `zpool.cache` file to another location as discussed in the preceding text.
- Determine which pool might have problems by using the `fmdump -eV` command to display the pools with reported fatal errors.
- Import the pools one by one, skipping the pools that are having problems, as described in the `fmdump` output.

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# Recommended Oracle Solaris ZFS Practices

This chapter describes recommended practices for creating, monitoring, and maintaining your ZFS storage pools and file systems.

This chapter covers the following topics:

- Recommended Storage Pool Practices.
- Recommended File System Practices.

For general ZFS tuning information that includes tuning for an Oracle database, see Chapter 3, Oracle Solaris ZFS Tunable Parameters in *Oracle Solaris 11.4 Tunable Parameters Reference Manual* .

## Recommended Storage Pool Practices

The following sections provide recommended practices for creating and monitoring ZFS storage pools. For information about troubleshooting storage pool problems, see Oracle Solaris ZFS Troubleshooting and Pool Recovery.

### General System Practices

- Keep system up-to-date with latest Oracle Solaris updates and releases
- Confirm that your controller honors cache flush commands so that you know your data is safely written, which is important before changing the pool's devices or splitting a mirrored storage pool. This is generally not a problem on Oracle/Sun hardware, but it is good practice to confirm that your hardware's cache flushing setting is enabled.
- Size memory requirements to actual system workload
  - With a known application memory footprint, such as for a database application, you might cap the ARC size so that the application will not need to reclaim its necessary memory from the ZFS cache.
  - Consider deduplication memory requirements
  - Identify ZFS memory usage with the following command:

```
$ mdb -k
> ::memstat
Page Summary                Pages                MB  %Tot
------------     ----------------  ----------------  ----
Kernel                     388117              1516   19%
ZFS File Data               81321               317    4%
Anon                        29928               116    1%
Exec and libs                1359                 5    0%
Page cache                   4890                19    0%
Free (cachelist)             6030                23    0%
Free (freelist)           1581183              6176   76%

Total                     2092828              8175
Physical                  2092827              8175
> $q
```

  - See Document 1663862.1, *Memory Management Between ZFS and Applications in Oracle Solaris 11.x*, in My Oracle Support (MOS) for tips on tuning the ZFS ARC cache. This document includes a script which you can use to modify the `user_reserve_hint_pct` and the `zfs_arc_max_percent` parameters.
  - Consider using ECC memory to protect against memory corruption. Silent memory corruption can potentially damage your data.
- Perform regular backups – Although a pool that is created with ZFS redundancy can help reduce down time due to hardware failures, it is not immune to hardware failures, power failures, or disconnected cables. Make sure you backup your data on a regular basis. If your data is important, it should be backed up. Different ways to provide copies of your data are:
  - Regular or daily ZFS snapshots
  - Weekly backups of ZFS pool data. You can use the `zpool split` command to create an exact duplicate of ZFS mirrored storage pool.
  - Monthly backups by using an enterprise-level backup product
- Hardware RAID
  - ZFS redundancy is recommended over hardware RAID for the following reasons:
    * When ZFS manages the storage redundancy, it not only detects underlying hardware issues but can also repair data inconsistencies.
    * Using ZFS redundancy has many benefits. For production environments, configure ZFS so that it can repair data inconsistencies. Use ZFS redundancy, such as RAID-Z, RAID-Z-2, RAID-Z-3, or mirroring. With such redundancy, faults in the underlying storage device or its connections to the host can be discovered and repaired by ZFS.
  - If you must use hardware RAID, present devices in JBOD mode so ZFS can manage the redundancy. In addition, follow these recommendations:
    * Monitor both the ZFS storage pool by using `zpool status` and the underlying LUNs by using your hardware RAID monitoring tools.
    * Promptly replace any failed devices.
    * Scrub your ZFS storage pools routinely, such as monthly, if you are using datacenter quality services.
    * Always have good, recent backups of your important data.

  See also Pool Creation Practices on Local or Network Attached Storage Arrays.
- Crash dumps consume more disk space, generally in the 1/2-3/4 size of physical memory range.

# ZFS Storage Pool Creation Practices

The following sections provide general and more specific pool practices.

## General Storage Pool Practices

- Use whole disks to enable disk write cache and provide easier maintenance. Creating pools on slices adds complexity to disk management and recovery.
- Use ZFS redundancy so that ZFS can repair data inconsistencies.
  - The following message is displayed when a non-redundant pool is created:

```
$ zpool create system1 c4t1d0 c4t3d0
'system1' successfully created, but with no redundancy; failure
of one device will cause loss of the pool
```

  - For mirrored pools, use mirrored disk pairs
  - For RAID-Z pools, group 3-9 disks per VDEV
  - Do not mix RAID-Z and mirrored components within the same pool. These pools are harder to manage and performance might suffer.
- Use hot spares to reduce down time due to hardware failures
- Use similar size disks so that I/O is balanced across devices
  - Smaller LUNs can be expanded to large LUNs
  - Do not expand LUNs from extremely varied sizes, such as 128 MB to 2 TB, to keep optimal metaslab sizes
- Consider creating a small root pool and larger data pools to support faster system recovery
- Recommended minimum pool size is 8 GB. Although the minimum pool size is 64 MB, anything less than 8 GB makes allocating and reclaiming free pool space more difficult.
- Recommended maximum pool size should comfortably fit your workload or data size. Do not try to store more data than you can routinely back up on a regular basis. Otherwise, your data is at risk due to some unforeseen event.

See also Pool Creation Practices on Local or Network Attached Storage Arrays.

## Root Pool Creation Practices

- **SPARC (SMI (VTOC))**: Create root pools with slices by using the `s*` identifier. Do not use the `p*` identifier. In general, a system's ZFS root pool is created when the system is installed. If you are creating a second root pool or re-creating a root pool, use syntax similar to the following on a SPARC system:

  ```
  $ zpool create rpool c0t1d0s0
  ```

  Or, create a mirrored root pool. For example:

  ```
  $ zpool create rpool mirror c0t1d0s0 c0t2d0s0
  ```

- **Oracle Solaris 11.1 x86 (EFI (GPT))**: Create root pools with whole disks by using the `d*` identifier. Do not use the `p*` identifier. In general, a system's ZFS root pool is created when the system is installed. If you are creating a second root pool or re-creating a root pool, use syntax similar to the following:

  ```
  $ zpool create rpool c0t1d0
  ```

  Or, create a mirrored root pool. For example:

  ```
  $ zpool create rpool mirror c0t1d0 c0t2d0
  ```

- The root pool must be created as a mirrored configuration or as a single-disk configuration. Neither a RAID-Z nor a striped configuration is supported. You cannot add additional disks to create multiple mirrored top-level virtual devices by using the `zpool add` command, but you can expand a mirrored virtual device by using the `zpool attach` command.
- The root pool cannot have a separate log device.
- Pool properties can be set during an AI installation. You can use the `lzjb` compression algorithm on root pools. You can use the `gzip` and `lz4` compression algorithms only on non-root pools.

- Do not rename the root pool after it is created by an initial installation. Renaming the root pool might cause an unbootable system.
- Do not create a root pool on a USB stick on a production system because root pool disks are critical for continuous operation, particularly in an enterprise environment. Consider using a system's internal disks for the root pool, or at least, use the same quality disks that you would use for your non-root data. In addition, a USB stick might not be large enough to support a dump volume size that is equivalent to at least 1/2 the size of physical memory.
- Rather than adding a hot spare to a root pool, consider creating a two- or a three-way mirror root pool. In addition, do not share a hot spare between a root pool and a data pool.
- Do not use a VMware thinly-provisioned device for a root pool device.

## Non-Root Pool Creation Practices

- Create non-root pools with whole disks by using the `d*` identifier. Do not use the `p*` identifier.
  - ZFS works best without any additional volume management software.
  - For better performance, use individual disks or at least LUNs made up of just a few disks. By providing ZFS with more visibility into the LUNs setup, ZFS is able to make better I/O scheduling decisions.
- Create redundant pool configurations across multiple controllers to reduce down time due to a controller failure.
  - **Mirrored storage pools** – Consume more disk space but generally perform better with small random reads.

    ```
    $ zpool create system1 mirror c1d0 c2d0 mirror c3d0 c4d0
    ```

  - **RAID-Z storage pools** – Can be created with 3 parity strategies, where parity equals 1 `raidz`), 2 `raidz2`), or 3 `raidz3`). A RAID-Z configuration maximizes disk space and generally performs well when data is written and read in large chunks (128K or more).
    - Consider a single-parity RAID-Z `raidz`) configuration with 2 VDEVs of 3 disks (2+1) each.

      ```
      $ zpool create rzpool raidz1 c1t0d0 c2t0d0 c3t0d0 raidz1 c1t1d0 c2t1d0 c3t1d0
      ```

    - A RAIDZ-2 configuration offers better data availability, and performs similarly to RAID-Z. RAIDZ-2 has significantly better mean time to data loss (MTTDL) than either RAID-Z or 2-way mirrors. Create a double-parity RAID-Z `raidz2`) configuration at 6 disks (4+2).

      ```
      $ zpool create rzpool raidz2 c0t1d0 c1t1d0 c4t1d0 c5t1d0 c6t1d0 c7t1d0
      raidz2 c0t2d0 c1t2d0 c4t2d0 c5t2d0 c6t2d0 c7t2d
      ```

    - A RAIDZ-3 configuration maximizes disk space and offers excellent availability because it can withstand 3 disk failures. Create a triple-parity RAID-Z (`raidz3`) configuration at 9 disks (6+3).

      ```
      $ zpool create rzpool raidz3 c0t0d0 c1t0d0 c2t0d0 c3t0d0 c4t0d0
      c5t0d0 c6t0d0 c7t0d0 c8t0d0
      ```

## Pool Creation Practices on Local or Network Attached Storage Arrays

Consider the following storage pool practices when creating an a ZFS storage pool on a storage array that is connected locally or remotely.

- If you create an pool on SAN devices and the network connection is slow, the pool's devices might be `UNAVAIL` for a period of time. You need to assess whether the network connection is appropriate for providing your data in a continuous fashion. Also, consider that if you are using SAN devices for your root pool, they might not be available as soon as the system is booted and the root pool's devices might also be `UNAVAIL`.
- Confirm with your array vendor that the disk array is not flushing its cache after a flush write cache request is issued by ZFS.
- Use whole disks, not disk slices, as storage pool devices so that Oracle Solaris ZFS activates the local small disk caches, which get flushed at appropriate times.
- For best performance, create one LUN for each physical disk in the array. Using only one large LUN can cause ZFS to queue up too few read I/O operations to actually drive the storage to optimal performance. Conversely, using many small LUNs could have the effect of swamping the storage with a large number of pending read I/O operations.
- A storage array that uses dynamic (or thin) provisioning software to implement virtual space allocation is not recommended for Oracle Solaris ZFS. When Oracle Solaris ZFS writes the modified data to free space, it writes to the entire LUN. The Oracle Solaris ZFS write process allocates all the virtual space from the storage array's point of view, which negates the benefit of dynamic provisioning.

  Consider that dynamic provisioning software might be unnecessary when using ZFS:

  – You can expand a LUN in an existing ZFS storage pool and it will use the new space.
  – Similar behavior works when a smaller LUN is replaced with a larger LUN.
  – If you assess the storage needs for your pool and create the pool with smaller LUNs that equal the required storage needs, then you can always expand the LUNs to a larger size if you need more space.
- Present individual devices in JBOD-mode and configure ZFS storage redundancy (mirror or RAID-Z) on this type of array so that ZFS can report and correct data inconsistencies.

## Pool Creation Practices for an Oracle Database

Consider the following storage pool practices when creating an Oracle database.

- Use a mirrored pool or hardware RAID for pools
- RAID-Z pools are generally not recommended for random read workloads
- Create a small separate pool with a separate log device for database redo logs
- Create a small separate pool for the archive log

For more information about tuning ZFS for an Oracle database, see Tuning ZFS for Database Products in *Oracle Solaris 11.4 Tunable Parameters Reference Manual* .

## Using ZFS Storage Pools in VirtualBox

- Virtual Box is configured to ignore cache flush commands from the underlying storage by default. This means that in the event of a system crash or a hardware failure, data could be lost.
- Enable cache flushing on Virtual Box by issuing the following command:

  ```
  VBoxManage setextradata vm-name "VBoxInternal/Devices/type/0/LUN#n/Config/
  IgnoreFlush" 0
  ```

  – *vm-name* – the name of the virtual machine

  - *type* – the controller type, either `piix3ide` (if you're using the usual IDE virtual controller) or `ahci`, if you're using a SATA controller
  - *n* – the disk number

## Storage Pool Practices for Performance

- In general, keep pool capacity below 90% for best performance. The percentage where performance might be impacted depends greatly on workload:
  - If data is mostly added (write once, remove never), then it's very easy for ZFS to find new blocks. In this case, the percentage can be higher than normal; maybe up to 95%.
  - If data is made of large files or large blocks (such as 128K files or 1MB blocks) and the data is removed in bulk operations, the percentage can be higher than normal; maybe up to 95%.
  - If a large percentage (more than 50%) of the pool is made up of 8k chunks (DBfiles, iSCSI Luns, or many small files) and have constant rewrites, then the 90% rule should be followed strictly.
  - If all of the data is small blocks that have constant rewrites, then you should monitor your pool closely once the capacity gets over 80%. The sign to watch for is increased disk IOPS to achieve the same level of client IOPS.
- Mirrored pools are recommended over RAID-Z pools for random read/write workloads
- Separate log devices
  - Recommended to improve synchronous write performance
  - With a high synchronous write load, prevents fragmentation of writing many log blocks in the main pool
- Separate cache devices are recommended to improve read performance
- Scrub/resilver - A very large RAID-Z pool with lots of devices will have longer scrub and resilver times
- Pool performance is slow – Use the `zpool status` command to rule out any hardware problems that are causing pool performance problems. If no problems show up in the `zpool status` command, use the `fmdump` command to display hardware faults or use the `fmdump -eV` command to review any hardware errors that have not yet resulted in a reported fault.

## ZFS Storage Pool Maintenance and Monitoring Practices

- Make sure that pool capacity is below 90% for best performance.

  Pool performance can degrade when a pool is very full and file systems are updated frequently, such as on a busy mail server. Full pools might cause a performance penalty, but no other issues. If the primary workload is immutable files, then keep pool in the 95-96% utilization range. Even with mostly static content in the 95-96% range, write, read, and resilvering performance might suffer.
  - Monitor pool and file system space to make sure that they are not full.
  - Consider using ZFS quotas and reservations to make sure file system space does not exceed 90% pool capacity.
- Monitor pool health
  - Monitor a redundant pool with `zpool status` and `fmdump` at least once per week

  - Monitor a non-redundant pool with `zpool status` and `fmdump` at least twice per week

- Run `zpool scrub` on a regular basis to identify data integrity problems.

  Scrub scheduling is enabled to run every 30 days by default. You can use the `scrubinterval` property to disable scrub scheduling or change the interval at which scrubs run. See the `zpool`(8) man page.

  - If you have consumer-quality drives, consider a weekly scrubbing schedule.
  - If you have datacenter-quality drives, consider a monthly scrubbing schedule.
  - You should also run a scrub prior to replacing devices or temporarily reducing a pool's redundancy to ensure that all devices are currently operational.

- Monitoring pool or device failures - Use `zpool status` as described below. Also use `fmdump` or `fmdump -eV` to see if any device faults or errors have occurred.

  - Redundant pools, monitor pool health with `zpool status` and `fmdump` on a weekly basis
  - Non-redundant pools, monitor pool health with `zpool status` and `fmdump` on a semiweekly basis

- Pool device is `UNAVAIL` or `OFFLINE` – If a pool device is not available, then check to see if the device is listed in the `format` command output. If the device is not listed in the `format` output, then it will not be visible to ZFS.

  If a pool device has `UNAVAIL` or `OFFLINE`, then this generally means that the device has failed or cable has disconnected, or some other hardware problem, such as a bad cable or bad controller has caused the device to be inaccessible.

- Consider configuring the `smtp-notify` service to notify you when a hardware component is diagnosed as faulty. For more information, see the Notification Parameters section of `smf`(7) and `smtp-notify`(8).

  By default, some notifications are set up automatically to be sent to the `root` user. If you add an alias for your user account as `root` in the `/etc/aliases` file, you will receive electronic mail notifications with information similar to the following:

```
SUNW-MSG-ID: ZFS-8000-8A, TYPE: Fault, VER: 1, SEVERITY: Critical
EVENT-TIME: Fri Jun 29 16:58:58 MDT 2012
...
SOURCE: zfs-diagnosis, REV: 1.0
EVENT-ID: 76c2d1d1-4631-4220-dbbc-a3574b1ee807
DESC: A file or directory in pool 'pond' could not be read due to corrupt data.
AUTO-RESPONSE: No automated response will occur.
IMPACT: The file or directory is unavailable.
REC-ACTION: Use 'fmadm faulty' to provide a more detailed view of this event.
Run 'zpool status -xv' and examine the list of damaged files to determine what
has been affected. Please refer to the associated reference document at
http://support.oracle.com/msg/ZFS-8000-8A for the latest service procedures
and policies regarding this diagnosis.
```

- Monitor your storage pool space – Use the `zpool list` command and the `zfs list` command to identify how much disk is consumed by file system data. ZFS snapshots can consume disk space and if they are not listed by the `zfs list` command, they can silently consume disk space. Use the `zfs list -t snapshot` command to identify disk space that is consumed by snapshots.

# Recommended File System Practices

The following sections describe recommended file system practices.

## Root File System Practices

- Consider keeping the root file system small and isolated from other non-root related data so that root pool recovery is faster.
- Do not include file systems in rpool/ROOT, which is a special container that requires no administration and should not contain any additional components.

## File System Creation Practices

The following sections describe ZFS file system creation practices.

- Create one file system per user for home directories
- Consider using file system quotas and reservations to manage and reserve disk space for important file systems
- Consider using user and group quotas to manage disk space in an environment with many users
- Use ZFS property inheritance to apply properties to many descendant file systems

## File System Creation Practices for an Oracle Database

Consider the following file system practices when creating an Oracle database.

- Match the ZFS `recordsize` property to the Oracle `db_block_size`.
- Create database table and index file systems in main database pool, using an 8 KB `recordsize` and the default `primarycache` value.
- Create temp data and undo table space file systems in the main database pool, using default `recordsize` and `primarycache` values.
- Create archive log file system in the archive pool, enabling compression and default `recordsize` value and `primarycache` set to `metadata`.

## Monitoring ZFS File System Practices

You should monitor your ZFS file systems to ensure they are available and to identify space consumption issues.

- Weekly, monitor file system space availability with the `zpool list` and `zfs list` commands rather than the `du` and `df` commands because legacy commands do not account for space that is consumed by descendant file systems or snapshots.

  For more information, see Resolving ZFS Space Issues.
- Display file system space consumption by using the `zfs list -o space` command.
- File system space can be unknowingly consumed by snapshots. You can display all dataset information by using the following syntax:

  ```
  $ zfs list -t all
  ```

- A separate `/var` file system is created automatically when a system is installed, but you should set a quota and reservation on this file system to ensure that it does not unknowingly consume root pool space.
- In addition, you can use the `fsstat` command to display file operation activity of ZFS file systems. Activity can be reported by mount point or by file system type. The following example shows general ZFS file system activity:

```
$ fsstat /
new  name   name  attr  attr lookup rddir  read read  write write
file remov  chng   get   set    ops   ops   ops bytes   ops bytes
832   589   286  837K 3.23K  2.62M 20.8K 1.15M 1.75G 62.5K  348M /
```

- Backups
  - Keep file system snapshots
  - Consider enterprise-level software for weekly and monthly backups
  - Store root pool snapshots on a remote system for bare metal recovery

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# Using Time Slider

This appendix describes Time Slider as a tool for certain snapshot management tasks. The appendix covers the following topics:



## About Time Slider

Time Slider provides a graphical way for Oracle Solaris desktop users to restore individual files or directories from automatically scheduled, incremental snapshots of home directories. If enabled, Time Slider takes a snapshot of every ZFS file system every 15 minutes, by default. These snapshots are then deleted again over time, such that only one snapshot is kept for each of the previous 24 hours, one for each of the previous 7 days, and one for each previous week that the Time Slider service was running.

Time Slider can automate periodic snapshots for any ZFS file system, including boot environments, even on non-desktop systems.

> **Note:**
>
> If you install the `desktop/time-slider` package, some desktop component dependencies might also be included in the installation.

Time Slider uses the following SMF services:

- `svc:/system/filesystem/zfs/auto-snapshot:frequent`: Takes one snapshot every 15 minutes
- `svc:/system/filesystem/zfs/auto-snapshot:hourly`: Takes one snapshot every hour
- `svc:/system/filesystem/zfs/auto-snapshot:daily`: Takes one snapshot every day
- `svc:/system/filesystem/zfs/auto-snapshot:weekly`: Takes one snapshot every week
- `svc:/system/filesystem/zfs/auto-snapshot:monthly`: Takes one snapshot every month
- `svc:/application/time-slider:default`: Manages automatic deletion of snapshots
- `svc:/application/time-slider/plugin:rsync`: Replicates each snapshot automatically to a specified external storage device

## Enabling and Disabling Time Slider

To configure Time Slider, you must be assigned the Time Slider Management rights profile. If the profile requires authentication, you will be prompted for a password to gain access to the configuration dialogs.

By default, Time Slider is disabled. To enable it, follow this procedure:

## How to Enable or Disable Time Slider

1. **On the desktop, click Activities to display the dock.**
2. **From the dock, click Show Applications, and then click Time Slider.**
3. **Select or deselect the Enable Time Slider option.**
4. **Click OK to select default settings.**

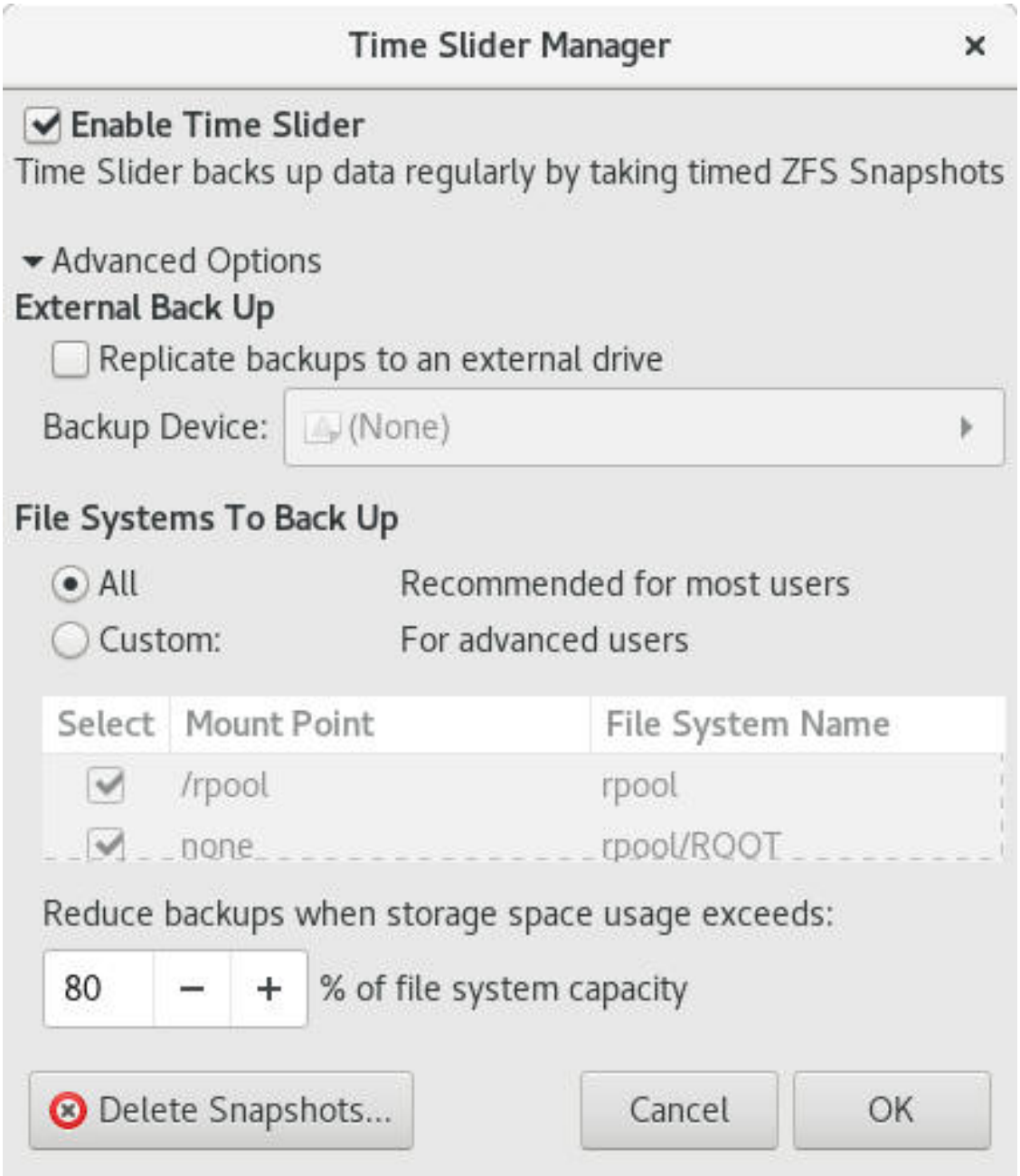
# Using Time Slider Advanced Options

Time Slider takes frequent snapshots of all the attached ZFS file systems These snapshots are taken every 15 minutes, hourly, daily, and weekly.

In turn, automatic snapshots are deleted as follows:

- `frequent` snapshots are deleted after 1 hour
- `hourly` snapshots are deleted after 1 day
- `daily` snapshots are deleted after 1 week
- `weekly` snapshots are deleted after 1 month
- Older snapshots are deleted when the file system becomes more than 80% full

When enabled, Time Slider provides a set of advanced options so you can customize snapshot processes as illustrated in the following figure:




- Select *Replicate backups to an external drive* to specify a different destination drive to store the snapshots.
- Select *Custom* to choose which files will have snapshots instead of using the default setting that creates snapshots for all files.
- Change the percentage number to set a threshold for storage capacity consumption which, when exceeded, triggers the deletion of older snapshots.
- Click *Delete Snapshots* to display a list of existing snapshots from which you can select those you want to delete.

**Note:**

Restoring snapshots is no longer supported in the desktop. To restore snapshots, as well as perform other snapshot management tasks, you will need to use the command line. See Working With Oracle Solaris ZFS Snapshots and Clones.

A

# Oracle Solaris ZFS Version Descriptions

This appendix describes available ZFS versions, features of each version, and the Oracle Solaris OS that provides the ZFS version and feature.

This appendix covers the following topics:

- Overview of ZFS Versions.
- ZFS Pool Versions.
- ZFS File System Versions.

## Overview of ZFS Versions

New ZFS pool and file system features are introduced and accessible by using a specific ZFS version that is available in Oracle Solaris releases. You can use the `zpool upgrade` or `zfs upgrade` to identify whether a pool or file system is at lower version than the currently running Oracle Solaris release provides. You can also use these commands to upgrade your pool and file system versions.

For information about using the `zpool upgrade` and `zfs upgrade` commands, see Upgrading ZFS File Systems and Upgrading ZFS Storage Pools.

## ZFS Pool Versions

The following table provides a list of ZFS pool versions that are available in the Oracle Solaris release. This list can be created using the `zpool upgrade -v` command.

| Version | Oracle Solaris Release | Description |
|---|---|---|
| 1 | Solaris 10 6/06 | Initial ZFS version |
| 2 | Solaris 10 11/06 | Ditto blocks (replicated metadata) |
| 3 | Solaris 10 11/06 | Hot spares and double parity RAID-Z |
| 4 | Solaris 10 8/07 | `zpool history` |
| 5 | Solaris 10 10/08 | `gzip` compression algorithm |
| 6 | Solaris 10 10/08 | `bootfs` pool property |
| 7 | Solaris 10 10/08 | Separate intent log devices |
| 8 | Solaris 10 10/08 | Delegated administration |
| 9 | Solaris 10 10/08 | `refquota` and `refreservation` properties |
| 10 | Solaris 10 5/09 | Cache devices |
| 11 | Solaris 10 10/09 | Improved scrub performance |
| 12 | Solaris 10 10/09 | Snapshot properties |
| 13 | Solaris 10 10/09 | `snapused` property |

| Version | Oracle Solaris Release | Description |
|---|---|---|
| 14 | Solaris 10 10/09 | `aclinherit passthrough-x` property |
| 15 | Solaris 10 10/09 | user and group space accounting |
| 16 | Solaris 10 9/10 | `stmf` property |
| 17 | Solaris 10 9/10 | Triple-parity RAID-Z |
| 18 | Solaris 10 9/10 | Snapshot user holds |
| 19 | Solaris 10 9/10 | Log device removal |
| 20 | Solaris 10 9/10 | `zle` (zero-length encoding) compression algorithm |
| 21 | Solaris 10 9/10 | Deduplication |
| 22 | Solaris 10 9/10 | Received properties |
| 23 | Solaris 10 8/11 | Slim ZIL |
| 24 | Solaris 10 8/11 | System attributes |
| 25 | Solaris 10 8/11 | Improved scrub stats |
| 26 | Solaris 10 8/11 | Improved snapshot deletion performance |
| 27 | Solaris 10 8/11 | Improved snapshot creation performance |
| 28 | Solaris 10 8/11 | Multiple vdev replacements |
| 29 | Solaris 10 8/11 | RAID-Z/mirror hybrid allocator |
| 30 | Solaris 11 11/11 | Encryption |
| 31 | Solaris 10 1/13 | Improved 'zfs list' performance |
| 32 | Solaris 10 1/13 | One MB blocksize |
| 33 | Oracle Solaris 11 11/11 | Improved share support |
| 34 | Oracle Solaris 11.1 | Sharing with inheritance |
| 35 | Oracle Solaris 11.2 | Sequential resilver |
| 36 | Oracle Solaris 11.3 | Efficient log block allocation |
| 37 | Oracle Solaris 11.3 | lz4 compression |
| 38 | Oracle Solaris 11.4 | xcopy with encryption |
| 39 | Oracle Solaris 11.4 | reduce resilver restart |
| 40 | Oracle Solaris 11.4 | Deduplication 2 |
| 41 | Oracle Solaris 11.4 | Asynchronous dataset destroy |
| 42 | Oracle Solaris 11.4 | Support for reguid |
| 43 | Oracle Solaris 11.4 | RAID-Z enhancements and cloud device support |
| 44 | Oracle Solaris 11.4 | Device Removal |
| 45 | Oracle Solaris 11.4 SRU 11 | Lazy deadlists |
| 46 | Oracle Solaris 11.4 SRU 12 | Compact file metadata for encryption |
| 47 | Oracle Solaris 11.4 SRU 21 | Property support for ZFS volumes |
| 48 | Oracle Solaris 11.4 SRU 45 | File retention |

| Version | Oracle Solaris Release | Description |
|---|---|---|
| 49 | Oracle Solaris 11.4 SRU 51 | Unicode versioning |
| 50 | Oracle Solaris 11.4 SRU 57 | Raw crypto replication |
| 51 | Oracle Solaris 11.4 SRU 63 | Retention onexpiry |
| 52 | Oracle Solaris 11.4 SRU 72 | `clonedir` mount point support |

# ZFS File System Versions

The following table lists the ZFS file system versions that are available in the Oracle Solaris release. Keep in mind that a feature that is available in a specific file system version requires a specific pool version.This list can be created using the `zfs upgrade -v` command.

| Version | Oracle Solaris Release | Description |
|---|---|---|
| 1 | Solaris 10 6/06 | Initial ZFS file system version |
| 2 | Solaris 10 10/08 | Enhanced directory entries |
| 3 | Solaris 10 10/08 | Case insensitivity and file system unique identifier (FUID) |
| 4 | Solaris 10 10/09 | `userquota` and `groupquota` properties |
| 5 | Solaris 10 8/11 | System attributes |
| 6 | Oracle Solaris 11.1 | Multilevel file system support |
| 7 | Oracle Solaris 11.4 SRU 45 | File retention |
| 8 | Oracle Solaris 11.4 SRU 51 | Unicode versioning |

# B

# ZFS Glossary

## B

### boot environment

A bootable Oracle Solaris environment consisting of a ZFS root file system and, optionally, other file systems mounted underneath it. Exactly one boot environment can be active at a time.

## C

### checksum

A 256-bit hash of the data in a file system block. The checksum capability can range from the simple and fast fletcher4 (the default) to cryptographically strong hashes such as SHA256.

### clone

A file system whose initial contents are identical to the contents of a snapshot.

For information about clones, see Overview of ZFS Clones.

## D

### dataset

A generic name for the following ZFS components: clones, file systems, snapshots, and volumes. Each dataset is identified by a unique name in the ZFS namespace.

For more information about datasets, see Managing Oracle Solaris ZFS File Systems.

### deduplication

The process of eliminating duplicate blocks of data in a ZFS file system. After removing duplicate blocks, the unique blocks are stored in the deduplication table.

## F

### file system

A ZFS dataset of type `filesystem` that is mounted within the standard system namespace and behaves like other file systems.

For more information about file systems, see Managing Oracle Solaris ZFS File Systems.

# M

## mirror

A virtual device that stores identical copies of data on two or more disks. If any disk in a mirror fails, any other disk in that mirror can provide the same data.

# P

## pool

A logical group of devices describing the layout and physical characteristics of the available storage. Disk space for datasets is allocated from a pool.

For more information about storage pools, see Managing Oracle Solaris ZFS Storage Pools.

# R

## RAID-Z

A virtual device that stores data and parity on multiple disks. For more information about RAID-Z, see RAID-Z Storage Pool Configuration.

## resilvering

The process of copying data from one device to another device. For example, if a mirror device is replaced or taken offline, the data from an up-to-date mirror device is copied to the newly restored mirror device. In traditional volume management products, this process is referred to as *mirror resynchronization*.

For more information about ZFS resilvering, see Viewing Resilvering Status.

## root pool

A ZFS pool that contains the boot file system.

# S

## snapshot

A read-only copy of a file system or volume at a given point in time.

For more information about snapshots, see Overview of ZFS Snapshots.

# V

## virtual device

A logical device in a pool, which can be a physical device, a file, or a collection of devices.

For more information about virtual devices, see Querying ZFS Storage Pool Status.

## volume

A dataset that represents a block device. For example, you can create a ZFS volume as a swap device.

For more information about ZFS volumes, see ZFS Volumes.

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## Symbols



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