Red Hat Enterprise Linux 7.3 Beta Storage Administration Guide

Deploying and configuring single-node storage in Red Hat Enterprise Linux 7

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Abstract

This guide provides instructions on how to effectively manage storage devices and file systems on Red Hat Enterprise Linux 7. It is intended for use by system administrators with basic to intermediate knowledge of Red Hat Enterprise Linux or Fedora. Note: This document is under development, is subject to substantial change, and is provided only as a preview. The included information and instructions should not be considered complete, and should be used with caution.

Table of Contents

Chapter 1. Overview

The *Storage Administration Guide* contains extensive information on supported file systems and data storage features in Red Hat Enterprise Linux 7. This book is intended as a quick reference for administrators managing single-node (that is, non-clustered) storage solutions.

The Storage Administration Guide is split into two parts: File Systems, and Storage Administration.

The File Systems part details the various file systems Red Hat Enterprise Linux 7 supports. It describes them and explains how best to utilize them.

The Storage Administration part details the various tools and storage administration tasks Red Hat Enterprise Linux 7 supports. It describes them and explains how best to utilize them.

1.1. What's New in Red Hat Enterprise Linux 7

Red Hat Enterprise Linux 7 features the following file system enhancements:

eCryptfs not included

As of Red Hat Enterprise Linux 7 eCryptfs is not included. Refer to Red Hat's Security Guide for information on encrypting file systems.

System Storage Manager

Red Hat Enterprise Linux 7 includes a new application called System Storage Manager. This provides a command-line interface to manage various storage technologies. For more information, see Chapter 15, *System Storage Manager (SSM)*.

XFS is the default File System

As of Red Hat Enterprise Linux 7, XFS is the default file system. For more information about the XFS file system, see Chapter 6, *The XFS File System*.

File system restructure

Red Hat Enterprise Linux 7 introduces a new file system structure. The directories **`/bin`**, **`/sbin`**, **`/lib`**, and **`/lib64`** are now nested under **`/usr`**.

Snapper

Red Hat Enterprise Linux 7 introduces a new tool called snapper that allows for the easy creation and management of snapshots for LVM and BTRFS. For more information refer to Chapter 13, *Creating and Maintaining Snapshots with Snapper*.

BTRFS (Technology Preview)

BTRFS is a local file system that aims to provide better performance and scalability, including integrated LVM operations. This file system is not fully supported by Red Hat and as such is a technology preview. For more information on Btrfs, see Chapter 3, *Btrfs (Technology Preview)*.

NFSv2 no longer supported

As of Red Hat Enterprise Linux 7, NFSv2 is no longer supported.

Part I. File Systems

The File Systems section provides information on the file system structure and maintenance, the Btrfs Technology Preview, and file systems that Red Hat fully supports: ext3, ext4, GFS2, XFS, NFS, and FS-Cache.

For an overview of Red Hat Enterprise Linux file systems and storage limits, see Red Hat Enterprise Linux technology capabilities and limits at Red Hat Knowledgebase.

Chapter 2. File System Structure and Maintenance

The file system structure is the most basic level of organization in an operating system. The way an operating system interacts with its users, applications, and security model nearly always depends on how the operating system organizes files on storage devices. Providing a common file system structure ensures users and programs can access and write files.

File systems break files down into two logical categories:

- Shareable vs. unsharable files
- Variable vs. static files

Shareable files can be accessed locally and by remote hosts; *unsharable* files are only available locally. *Variable* files, such as documents, can be changed at any time; *static* files, such as binaries, do not change without an action from the system administrator.

Categorizing files in this manner helps correlate the function of each file with the permissions assigned to the directories which hold them. How the operating system and its users interact with a file determines the directory in which it is placed, whether that directory is mounted with read-only or read/write permissions, and the level of access each user has to that file. The top level of this organization is crucial; access to the underlying directories can be restricted, otherwise security problems could arise if, from the top level down, access rules do not adhere to a rigid structure.

2.1. Overview of Filesystem Hierarchy Standard (FHS)

Red Hat Enterprise Linux uses the *Filesystem Hierarchy Standard* (*FHS*) file system structure, which defines the names, locations, and permissions for many file types and directories.

The FHS document is the authoritative reference to any FHS-compliant file system, but the standard leaves many areas undefined or extensible. This section is an overview of the standard and a description of the parts of the file system not covered by the standard.

The two most important elements of FHS compliance are:

- Compatibility with other FHS-compliant systems
- The ability to mount a **/usr/** partition as read-only. This is especially crucial, since **/usr/** contains common executables and should not be changed by users. In addition, since **/usr/** is mounted as read-only, it should be mountable from the CD-ROM drive or from another machine via a read-only NFS mount.

2.1.1. FHS Organization

The directories and files noted here are a small subset of those specified by the FHS document. Refer to the latest FHS documentation for the most complete information at http://www.pathname.com/fhs/.

Note

What directories are available depends on what is installed on any given system. The following lists are only an example of what may be found.

2.1.1.1. Gathering File System Information

The **df** command reports the system's disk space usage. Its output looks similar to the following:

Example 2.1. df command output

```
Filesystem           1K-blocks      Used Available Use% Mounted on
/dev/mapper/VolGroup00-LogVol00
                       11675568   6272120   4810348  57% / /dev/sda1
                  100691      9281     86211  10% /boot
none                     322856         0    322856   0% /dev/shm
```

By default, **df** shows the partition size in 1 kilobyte blocks and the amount of used and available disk space in kilobytes. To view the information in megabytes and gigabytes, use the command **df -h**. The **-h** argument stands for "human-readable" format. The output for **df -h** looks similar to the following:

Example 2.2. df -h command output

```
Filesystem            Size  Used Avail Use% Mounted on
/dev/mapper/VolGroup00-LogVol00
                        12G  6.0G  4.6G  57% / /dev/sda1
   99M  9.1M   85M  10% /boot
none    316M     0  316M   0% /dev/shm
```

Note

In the above examples, the mounted partition **/dev/shm** represents the system's virtual memory file system.

The **du** command displays the estimated amount of space being used by files in a directory, displaying the disk usage of each subdirectory. The last line in the output of **du** shows the total disk usage of the directory; to see only the total disk usage of a directory in human-readable format, use **du -hs**. For more options, refer to **man du**.

To view the system's partitions and disk space usage in a graphical format, use the Gnome **System Monitor** by clicking on **Applications** → **System Tools** → **System Monitor** or using the command **gnome-system-monitor**. Select the **File Systems** tab to view the system's partitions. The figure below illustrates the **File Systems** tab.

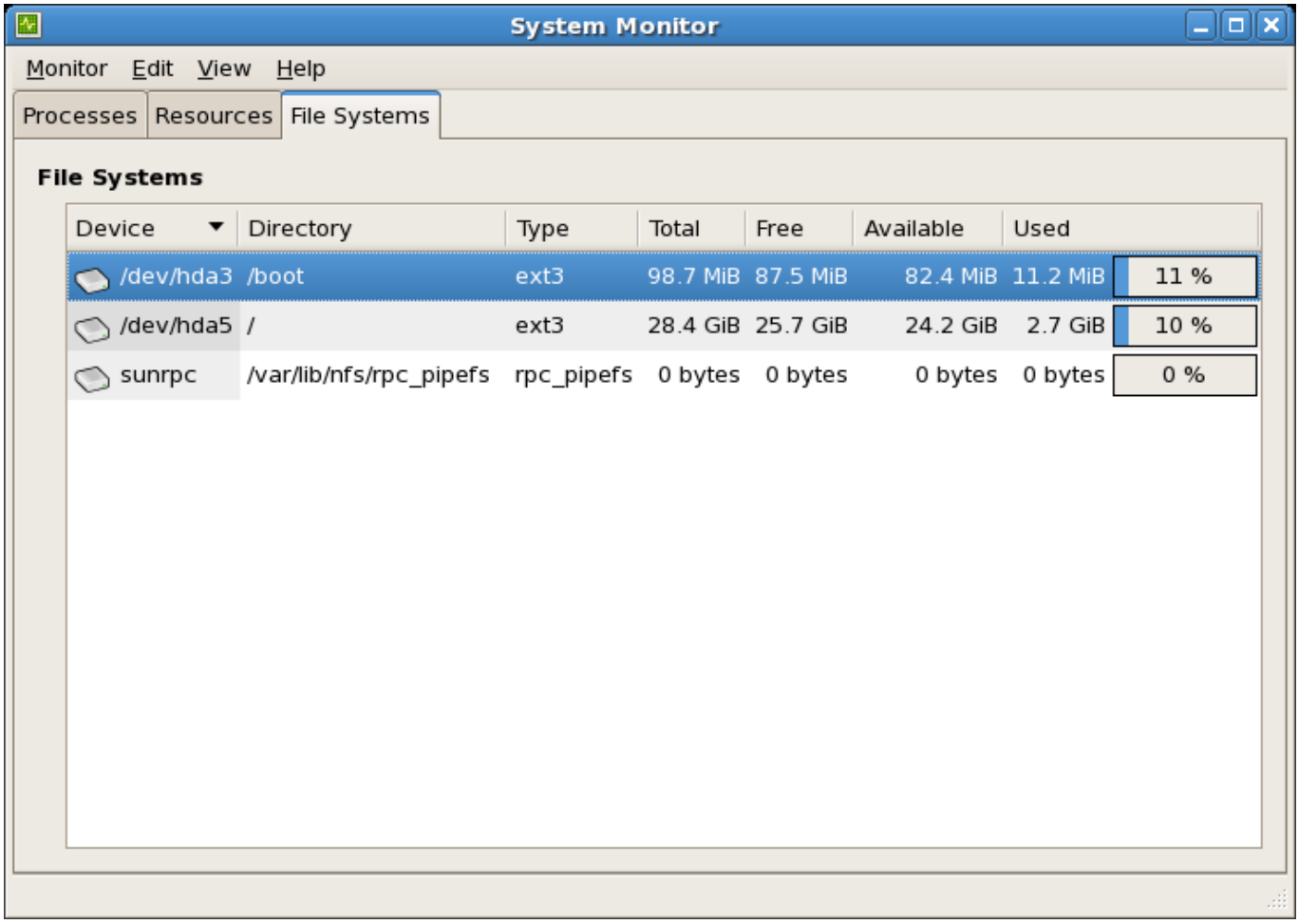


Figure 2.1. GNOME System Monitor File Systems tab

2.1.1.2. The `/boot/` Directory

The **/boot/** directory contains static files required to boot the system, for example, the Linux kernel. These files are essential for the system to boot properly.

Warning

Do not remove the **/boot/** directory. Doing so renders the system unbootable.

2.1.1.3. The `/dev/` Directory

The **/dev/** directory contains device nodes that represent the following device types:

- devices attached to the system;
- virtual devices provided by the kernel.

These device nodes are essential for the system to function properly. The **udevd** daemon creates and removes device nodes in **/dev/** as needed.

Devices in the **/dev/** directory and subdirectories are defined as either *character* (providing only a serial stream of input and output, for example, mouse or keyboard) or *block* (accessible randomly, such as a hard drive or a floppy drive). If GNOME or KDE is installed, some storage devices are automatically detected when connected (such as with USB) or inserted (such as a CD or DVD drive),

and a pop-up window displaying the contents appears.

Table 2.1. Examples of common files in the /dev directory

File	Description
/dev/hda	The master device on the primary IDE channel.
/dev/hdb	The slave device on the primary IDE channel.
/dev/tty0	The first virtual console.
/dev/tty1	The second virtual console.
/dev/sda	The first device on the primary SCSI or SATA channel.
/dev/lp0	The first parallel port.

A valid block device can be one of two types of entries:

A mapped device

A logical volume in a volume group, for example, **/dev/mapper/VolGroup00-LogVol02**.

A static device

A traditional storage volume, for example, **/dev/*sdbX***, where *sdb* is a storage device name and *X* is the partition number. **/dev/sdb*X*** can also be **/dev/disk/by-id/*WWID***, or **/dev/disk/by-uuid/*UUID***, (see Section 25.7, “Persistent Naming” for more information on both these options).

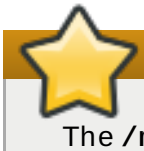
2.1.1.4. The /etc/ Directory

The **/etc/** directory is reserved for configuration files that are local to the machine. It should contain no binaries; any binaries should be moved to **/usr/bin/** or **/usr/sbin/**.

For example, the **/etc/skel/** directory stores "skeleton" user files, which are used to populate a home directory when a user is first created. Applications also store their configuration files in this directory and may reference them when executed. The **/etc/exports** file controls which file systems export to remote hosts.

2.1.1.5. The /mnt/ Directory

The **/mnt/** directory is reserved for temporarily mounted file systems, such as NFS file system mounts. For all removable storage media, use the **/media/** directory. Automatically detected removable media will be mounted in the **/media** directory.



Important

The **/mnt** directory must not be used by installation programs.

2.1.1.6. The /opt/ Directory

The **/opt/** directory is normally reserved for software and add-on packages that are not part of the default installation. A package that installs to **/opt/** creates a directory bearing its name, for example, **/opt/*packagename*/**. In most cases, such packages follow a predictable subdirectory structure; most store their binaries in **/opt/*packagename*/bin/** and their **man** pages in

/opt/*packagename*/man/.

2.1.1.7. The /proc/ Directory

The **/proc/** directory contains special files that either extract information from the kernel or send information to it. Examples of such information include system memory, CPU information, and hardware configuration. For more information about **/proc/**, refer to Section 2.3, “The /proc Virtual File System”.

2.1.1.8. The /srv/ Directory

The **/srv/** directory contains site-specific data served by a Red Hat Enterprise Linux system. This directory gives users the location of data files for a particular service, such as FTP, WWW, or CVS. Data that only pertains to a specific user should go in the **/home/** directory.

2.1.1.9. The /sys/ Directory

The **/sys/** directory utilizes the new **sysfs** virtual file system specific to the kernel. With the increased support for hot plug hardware devices in the kernel, the **/sys/** directory contains information similar to that held by **/proc/**, but displays a hierarchical view of device information specific to hot plug devices.

2.1.1.10. The /usr/ Directory

The **/usr/** directory is for files that can be shared across multiple machines. The **/usr/** directory is often on its own partition and is mounted read-only. At a minimum, **/usr/** should contain the following subdirectories:

/usr/bin

This directory is used for binaries.

/usr/etc

This directory is used for system-wide configuration files.

/usr/games

This directory stores games.

/usr/include

This directory is used for C header files.

/usr/kerberos

This directory is used for Kerberos-related binaries and files.

/usr/lib

This directory is used for object files and libraries that are not designed to be directly utilized by shell scripts or users.

As of Red Hat Enterprise Linux 7.0, the **/lib/** directory has been merged with **/usr/lib**. It now also contains libraries needed to execute the binaries in **/usr/bin/** and **/usr/sbin/**. These shared library images are used to boot the system or execute commands within the root file system.

/usr/libexec

This directory contains small helper programs called by other programs.

/usr/sbin

As of Red Hat Enterprise Linux 7.0, **/sbin** has been moved to **/usr/sbin**. This means that it contains all system administration binaries, including those essential for booting, restoring, recovering, or repairing the system. The binaries in **/usr/sbin/** require root privileges to use.

/usr/share

This directory stores files that are not architecture-specific.

/usr/src

This directory stores source code.

/usr/tmp linked to /var/tmp

This directory stores temporary files.

The **/usr/** directory should also contain a **/local/** subdirectory. As per the FHS, this subdirectory is used by the system administrator when installing software locally, and should be safe from being overwritten during system updates. The **/usr/local** directory has a structure similar to **/usr/**, and contains the following subdirectories:

- **/usr/local/bin**
- **/usr/local/etc**
- **/usr/local/games**
- **/usr/local/include**
- **/usr/local/lib**
- **/usr/local/libexec**
- **/usr/local/sbin**
- **/usr/local/share**
- **/usr/local/src**

Red Hat Enterprise Linux's usage of **/usr/local/** differs slightly from the FHS. The FHS states that **/usr/local/** should be used to store softwarethat should remain safe from system software upgrades. Since the **RPM Package Manager** can perform software upgrades safely, it is not necessary to protect files by storing them in **/usr/local/**.

Instead, Red Hat Enterprise Linux uses **/usr/local/** for software local to the machine. For instance, if the **/usr/** directory is mounted as a read-only NFS share from a remote host, it is still possible to install a package or program under the **/usr/local/** directory.

2.1.1.11. The /var/ Directory

Since the FHS requires Linux to mount **/usr/** as read-only, any programs that write log files or need **spool/** or **lock/** directories should write them to the **/var/** directory. The FHS states **/var/** is for variable data, which includes spool directories and files, logging data, transient and temporary files.

Below are some of the directories found within the **/var/** directory:

- **/var/account/**
- **/var/arpwatch/**
- **/var/cache/**
- **/var/crash/**
- **/var/db/**
- **/var/empty/**
- **/var/ftp/**
- **/var/gdm/**
- **/var/kerberos/**
- **/var/lib/**
- **/var/local/**
- **/var/lock/**
- **/var/log/**
- **/var/mail** linked to **/var/spool/mail/**
- **/var/mailman/**
- **/var/named/**
- **/var/nis/**
- **/var/opt/**
- **/var/preserve/**
- **/var/run/**
- **/var/spool/**
- **/var/tmp/**
- **/var/tux/**
- **/var/www/**
- **/var/yp/**

Important

The **/var/run/media/*user*** directory contains subdirectories used as mount points for removable media such as USB storage media, DVDs, CD-ROMs, and Zip disks. Note that previously, the **/media/** directory was used for this purpose.

System log files, such as **messages** and **lastlog**, go in the **/var/log/** directory. The **/var/lib/rpm/** directory contains RPM system databases. Lock files go in the **/var/lock/** directory, usually in directories for the program using the file. The **/var/spool/** directory has subdirectories that store data files for some programs. These subdirectories include:

- **/var/spool/at/**
- **/var/spool/clientmqueue/**
- **/var/spool/cron/**
- **/var/spool/cups/**
- **/var/spool/exim/**
- **/var/spool/lpd/**
- **/var/spool/mail/**
- **/var/spool/mailman/**
- **/var/spool/mqueue/**
- **/var/spool/news/**
- **/var/spool/postfix/**
- **/var/spool/repackage/**
- **/var/spool/rwho/**
- **/var/spool/samba/**
- **/var/spool/squid/**
- **/var/spool/squirrelmail/**
- **/var/spool/up2date/**
- **/var/spool/uucp/**
- **/var/spool/uucppublic/**
- **/var/spool/vbox/**

2.2. Special Red Hat Enterprise Linux File Locations

Red Hat Enterprise Linux extends the FHS structure slightly to accommodate special files.

Most files pertaining to RPM are kept in the **/var/lib/rpm/** directory. For more information on RPM, refer to **man rpm**.

The **/var/cache/yum/** directory contains files used by the **Package Updater**, including RPM header information for the system. This location may also be used to temporarily store RPMs downloaded while updating the system. For more information about the Red Hat Network, refer to the documentation online at https://rhn.redhat.com/.

Another location specific to Red Hat Enterprise Linux is the **/etc/sysconfig/** directory. This directory stores a variety of configuration information. Many scripts that run at boot time use the files in this directory.

2.3. The /proc Virtual File System

Unlike most file systems, **/proc** contains neither text nor binary files. Instead, it houses *virtual files*; as such, **/proc** is normally referred to as a virtual file system. These virtual files are typically zero bytes in size, even if they contain a large amount of information.

The **/proc** file system is not used for storage. Its main purpose is to provide a file-based interface to hardware, memory, running processes, and other system components. Real-time information can be retrieved on many system components by viewing the corresponding **/proc** file. Some of the files within **/proc** can also be manipulated (by both users and applications) to configure the kernel.

The following **/proc** files are relevant in managing and monitoring system storage:

/proc/devices

Displays various character and block devices that are currently configured.

/proc/filesystems

Lists all file system types currently supported by the kernel.

/proc/mdstat

Contains current information on multiple-disk or RAID configurations on the system, if they exist.

/proc/mounts

Lists all mounts currently used by the system.

/proc/partitions

Contains partition block allocation information.

For more information about the **/proc** file system, refer to the Red Hat Enterprise Linux 7 *Deployment Guide*.

2.4. Discard unused blocks

Batch discard and online discard operations are features of mounted file systems that discard blocks not in use by the file system. They are useful for both solid-state drives and thinly-provisioned storage.

Batch discard operations are run explicitly by the user with the **fstrim** command. This command discards all unused blocks in a file system that match the user's criteria. Both operation types are supported for use with ext4 file systems as of Red Hat Enterprise Linux 6.2 and later so long as the block device underlying the file system supports physical discard operations. This is also the case with XFS file systems as of Red Hat Enterprise Linux 6.4 and later. Physical discard operations are supported if the value of **/sys/block/*device*/queue/discard_max_bytes** is not zero.

Online discard operations are specified at mount time with the **-o discard** option (either in **/etc/fstab** or as part of the **mount** command), and run in realtime without user intervention. Online discard operations only discard blocks that are transitioning from used to free. Online discard operations are supported on ext4 file systems as of Red Hat Enterprise Linux 6.2 and later, and on XFS file systems as of Red Hat Enterprise Linux 6.4 and later.

Red Hat recommends batch discard operations unless the system's workload is such that batch discard is not feasible, or online discard operations are necessary to maintain performance.

Chapter 3. Btrfs (Technology Preview)

Btrfs is a next generation Linux file system that offers advanced management, reliability, and scalability features. It is unique in offering snapshots, compression, and integrated device management.

Important

BTRFS is a Technology Preview in Red Hat Enterprise Linux 7.

3.1. Creating a btrfs File System

In order to make a basic btrfs file system, use the following command:

```
# mkfs.btrfs /dev/device
```

For more information on creating btrfs file systems with added devices and specifying multi-device profiles for metadata and data, refer to Section 3.4, “Integrated Volume Management of Multiple Devices”.

3.2. Mounting a btrfs file system

To mount any device in the btrfs file system use the following command:

```
# mount /dev/device /mount-point
```

Other useful mount options include:

device=*/dev/name*

Appending this option to the mount command tells btrfs to scan the named device for a btrfs volume. This is used to ensure the mount will succeed as attempting to mount devices that are not btrfs will cause the mount to fail.

Note

This does not mean all devices will be added to the file system, it only scans them.

max_inline=*number*

Use this option to set the maximum amount of space (in bytes) that can be used to inline data within a metadata B-tree leaf. The default is 8192 bytes. For 4k pages it is limited to 3900 bytes due to additional headers that need to fit into the leaf.

alloc_start=*number*

Use this option to set where in the disk allocations start.

thread_pool=*number*

Use this option to assign the number of worker threads allocated.

discard

Use this option to enable discard/TRIM on freed blocks.

noacl

Use this option to disable the use of ACL's.

space_cache

Use this option to store the free space data on disk to make caching a block group faster. This is a persistent change and is safe to boot into old kernels.

nospace_cache

Use this option to disable the above **space_cache**.

clear_cache

Use this option to clear all the free space caches during mount. This is a safe option but will trigger the space cache to be rebuilt. As such, leave the file system mounted in order to let the rebuild process finish. This mount option is intended to be used once and only after problems are apparent with the free space.

enospc_debug

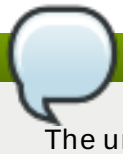
This option is used to debug problems with "no space left".

recovery

Use this option to enable autorecovery upon mount.

3.3. Resizing a btrfs file system

It is not possible to resize a btrfs file system but it is possible to resize each of the devices it uses. If there is only one device in use then this works the same as resizing the file system. If there are multiple devices in use then they must be manually resized to achieve the desired result.



Note

The unit size is not case specific; it accepts both **G** or **g** for GiB.

The command does not accept **t** for terabytes or **p** for petabytes. It only accepts **k**, **m**, and **g**.

Enlarging a btrfs File System

To enlarge the file system on a single device, use the command:

```
# btrfs filesystem resize amount /mount-point
```

For example:

```
# btrfs filesystem resize +200M /btrfssingle
Resize '/btrfssingle' of '+200M'
```

To enlarge a multi-device file system, the device to be enlarged must be specified. First, show all devices that have a btrfs file system at a specified mount point:

```
# btrfs filesystem show /mount-point
```

For example:

```
# btrfs filesystem show /btrfstest
Label: none  uuid: 755b41b7-7a20-4a24-abb3-45fdbed1ab39
 Total devices 4 FS bytes used 192.00KiB
 devid    1 size 1.00GiB used 224.75MiB path /dev/vdc
 devid    2 size 524.00MiB used 204.75MiB path /dev/vdd
 devid    3 size 1.00GiB used 8.00MiB path /dev/vde
 devid    4 size 1.00GiB used 8.00MiB path /dev/vdf

Btrfs v3.16.2
```

Then, after identifying the **devid** of the device to be enlarged, use the following command:

```
# btrfs filesystem resize devid:amount /mount-point
```

For example:

```
# btrfs filesystem resize 2:+200M /btrfstest
Resize '/btrfstest/' of '2:+200M'
```

Note

The *amount* can also be **max** instead of a specified amount. This will use all remaining free space on the device.

Shrinking a btrfs File System

To shrink the file system on a single device, use the command:

```
# btrfs filesystem resize amount /mount-point
```

For example:

```
# btrfs filesystem resize -200M /btrfssingle
Resize '/btrfssingle' of '-200M'
```

To shrink a multi-device file system, the device to be shrunk must be specified. First, show all devices that have a btrfs file system at a specified mount point:

```
# btrfs filesystem show /mount-point
```

For example:

```
# btrfs filesystem show /btrfstest
Label: none  uuid: 755b41b7-7a20-4a24-abb3-45fdbed1ab39
 Total devices 4 FS bytes used 192.00KiB
 devid    1 size 1.00GiB used 224.75MiB path /dev/vdc
 devid    2 size 524.00MiB used 204.75MiB path /dev/vdd
 devid    3 size 1.00GiB used 8.00MiB path /dev/vde
 devid    4 size 1.00GiB used 8.00MiB path /dev/vdf

Btrfs v3.16.2
```

Then, after identifying the **devid** of the device to be shrunk, use the following command:

```
# btrfs filesystem resize devid:amount /mount-point
```

For example:

```
# btrfs filesystem resize 2:-200M /btrfstest
Resize '/btrfstest' of '2:-200M'
```

Set the File System Size

To set the file system to a specific size on a single device, use the command:

```
# btrfs filesystem resize amount /mount-point
```

For example:

```
# btrfs filesystem resize 700M /btrfssingle
Resize '/btrfssingle' of '700M'
```

To set the file system size of a multi-device file system, the device to be changed must be specified. First, show all devices that have a btrfs file system at the specified mount point:

```
# btrfs filesystem show /mount-point
```

For example:

```
# btrfs filesystem show /btrfstest
Label: none  uuid: 755b41b7-7a20-4a24-abb3-45fdbed1ab39
 Total devices 4 FS bytes used 192.00KiB
 devid    1 size 1.00GiB used 224.75MiB path /dev/vdc
 devid    2 size 724.00MiB used 204.75MiB path /dev/vdd
 devid    3 size 1.00GiB used 8.00MiB path /dev/vde
 devid    4 size 1.00GiB used 8.00MiB path /dev/vdf

Btrfs v3.16.2
```

Then, after identifying the **devid** of the device to be changed, use the following command:

```
# btrfs filesystem resize devid:amount /mount-point
```

For example:

```
# btrfs filesystem resize 2:300M /btrfstest
Resize '/btrfstest' of '2:300M'
```

3.4. Integrated Volume Management of Multiple Devices

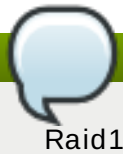
A btrfs file system can be created on top of many devices, and more devices can be added after the file system has been created. By default, metadata will be mirrored across two devices and data will be striped across all devices present, however if only one device is present, metadata will be duplicated on that device.

3.4.1. File System Creation with Multiple Devices

The **mkfs.btrfs** command, as detailed in Section 3.1, “Creating a btrfs File System”, accepts the options **-d** for data, and **-m** for metadata. Valid specifications are:

- **raid0**
- **raid1**
- **raid10**
- **dup**
- **single**

The **-m single** option instructs that no duplication of metadata is done. This may be desired when using hardware raid.



Note

Raid10 requires at least four devices to run correctly.

Example 3.1. Creating a raid10 btrfs file system

Create a file system across four devices (metadata mirrored, data striped).

```
# mkfs.btrfs /dev/device1 /dev/device2 /dev/device3 /dev/device4
```

Stripe the metadata without mirroring.

```
# mkfs.btrfs -m raid0 /dev/device1 /dev/device2
```

Use raid10 for both data and metadata.

```
# mkfs.btrfs -m raid10 -d raid10 /dev/device1 /dev/device2 /dev/device3
/dev/device4
```

Do not duplicate metadata on a single drive.

```
# mkfs.btrfs -m single /dev/device
```

Use the **single** option to use the full capacity of each drive when the drives are different sizes.

```
# mkfs.btrfs -d single /dev/device1 /dev/device2 /dev/device3
```

To add a new device to an already created multi-device file system, use the following command:

```
# btrfs device add /dev/device1 /mount-point
```

After rebooting or reloading the btrfs module, use the **btrfs device scan** command to discover all multi-device file systems. See Section 3.4.2, “Device scanning btrfs multiple devices” for more information.

3.4.2. Device scanning btrfs multiple devices

Use **btrfs device scan** to scan all block devices under **/dev** and probe for btrfs volumes. This must be performed after loading the btrfs module if running with more than one device in a file system.

To scan all devices, use the following command:

```
# btrfs device scan
```

To scan a single device, use the following command:

```
# btrfs device scan /dev/device
```

3.4.3. Adding new devices to a btrfs file system

Use the **btrfs filesystem show** command to list all the btrfs file systems and which devices they include.

The **btrfs device add** command is used to add new devices to a mounted file system.

The **btrfs filesystem balance** command balances (restripes) the allocated extents across all existing devices.

An example of all these commands together to add a new device is as follows:

Example 3.2. Add a new device to an btrfs file system

First, create and mount a btrfs file system. Refer to Section 3.1, “Creating a btrfs File System” for more information on how to create a btrfs file system, and to Section 3.2, “Mounting a btrfs file system” for more information on how to mount a btrfs file system.

```
# mkfs.btrfs /dev/device1
# mount /dev/device1
```

Next, add a second device to the mounted btrfs file system.

```
# btrfs device add /dev/device2 /mount-point
```

The metadata and data on these devices are still stored only on **/dev/*device1***. It must now be balanced to spread across all devices.

```
# btrfs filesystem balance /mount-point
```

Balancing a file system will take some time as it reads all of the file system's data and metadata and rewrites it across the new device.

3.4.4. Converting a btrfs file system

To convert a non-raid file system to a raid, add a device and run a balance filter that changes the chunk allocation profile.

Example 3.3. Converting a btrfs file system

To convert an existing single device system, **/dev/sdb1** in this case, into a two device, raid1 system in order to protect against a single disk failure, use the following commands:

```
# mount /dev/sdb1 /mnt
# btrfs device add /dev/sdc1 /mnt
# btrfs balance start -dconvert=raid1 -mconvert=raid1 /mnt
```

Important

If the metadata is not converted from the single-device default, it remains as DUP. This does not guarantee that copies of the block are on separate devices. If data is not converted it does not have any redundant copies at all.

3.4.5. Removing btrfs devices

Use the **btrfs device delete** command to remove an online device. It redistributes any extents in use to other devices in the file system in order to be safely removed.

Example 3.4. Removing a device on a btrfs file system

First create and mount a few btrfs file systems.

```
# mkfs.btrfs /dev/sdb /dev/sdc /dev/sdd /dev/sde
# mount /dev/sdb /mnt
```

Add some data to the file system.

Finally, remove the required device.

```
# btrfs device delete /dev/sdc /mnt
```

3.4.6. Replacing failed devices on a btrfs file system

Section 3.4.5, “Removing btrfs devices” can be used to remove a failed device provided the super block can still be read. However, if a device is missing or the super block corrupted, the file system will need to be mounted in a degraded mode:

```
# mkfs.btrfs -m raid1 /dev/sdb /dev/sdc /dev/sdd /dev/sde


  ssd is destroyed or removed, use -o degraded to force the mount
  to ignore missing devices


# mount -o degraded /dev/sdb /mnt


  'missing' is a special device name


# btrfs device delete missing /mnt
```

The command **btrfs device delete missing** removes the first device that is described by the file system metadata but not present when the file system was mounted.

Important

It is impossible to go below the minimum number of devices required for the specific raid layout, even including the missing one. It may be required to add a new device in order to remove the failed one.

For example, for a raid1 layout with two devices, if a device fails it is required to:

1. mount in degraded mode,
2. add a new device,
3. and, remove the missing device.

3.4.7. Registering a btrfs file system in /etc/fstab

If you do not have an **initrd** or it does not perform a btrfs device scan, it is possible to mount a multi-volume **btrfs** file system by passing all the devices in the file system explicitly to the **mount** command.

Example 3.5. Example /etc/fstab entry

An example of a suitable **/etc/fstab** entry would be:

```
/dev/sdb    /mnt    btrfs
device=/dev/sdb,device=/dev/sdc,device=/dev/sdd,device=/dev/sde    0
```

Note that using universally unique identifiers (UUIDs) also works and is more stable than using device paths.

3.5. SSD Optimization

Using the btrfs file system can optimize SSD. There are two ways this can be done.

The first way is **mkfs.btrfs** turns off metadata duplication on a single device when **/sys/block/*device*/queue/rotational** is zero for the single specified device. This is equivalent to specifying **-m single** on the command line. It can be overridden and duplicate metadata forced by providing the **-m dup** option. Duplication is not required due to SSD firmware potentially losing both copies. This wastes space and is a performance cost.

The second way is through a group of SSD mount options: **ssd**, **nossd**, and **ssd_spread**.

The **ssd** option does several things:

- It allows larger metadata cluster allocation.
- It allocates data more sequentially where possible.
- It disables btree leaf rewriting to match key and block order.
- It commits log fragments without batching multiple processes.

Note

The **ssd** mount option only enables the ssd option. Use the **nossd** option to disable it.

Some SSDs perform best when reusing block numbers often, while others perform much better when clustering strictly allocates big chunks of unused space. By default, **mount -o ssd** will find groupings of blocks where there are several free blocks that might have allocated blocks mixed in. The command **mount -o ssd_spread** ensures there are no allocated blocks mixed in. This improves performance on lower end SSDs.

Note

The **ssd_spread** option enables both the **ssd** and the **ssd_spread** options. Use the **nossd** to disable both these options.

The **ssd_spread** option is never automatically set if none of the ssd options are provided and any of the devices are non-rotational.

These options will all need to be tested with your specific build to see if their use improves or reduces performance, as each combination of SSD firmware and application loads are different.

3.6. btrfs references

The man page **btrfs(8)** covers all important management commands. In particular this includes:

- All the subvolume commands for managing snapshots.
- The **device** commands for managing devices.

- The **scrub**, **balance**, and **defragment** commands.

The man page **mkfs.btrfs(8)** contains information on creating a btrfs file system including all the options regarding it.

The man page **btrfsck(8)** for information regarding **fsck** on btrfs systems.

Chapter 4. The Ext3 File System

The ext3 file system is essentially an enhanced version of the ext2 file system. These improvements provide the following advantages:

Availability

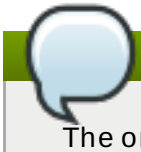
After an unexpected power failure or system crash (also called an *unclean system shutdown*), each mounted ext2 file system on the machine must be checked for consistency by the **e2fsck** program. This is a time-consuming process that can delay system boot time significantly, especially with large volumes containing a large number of files. During this time, any data on the volumes is unreachable.

It is possible to run **fsck -n** on a live filesystem. However, it will not make any changes and may give misleading results if partially written metadata is encountered.

If LVM is used in the stack, another option is to take an LVM snapshot of the filesystem and run **fsck** on it instead.

Finally, there is the option to remount the filesystem as read only. All pending metadata updates (and writes) are then forced to the disk prior to the remount. This ensures the filesystem is in a consistent state, provided there is no previous corruption. It is now possible to run **fsck -n**.

The journaling provided by the ext3 file system means that this sort of file system check is no longer necessary after an unclean system shutdown. The only time a consistency check occurs using ext3 is in certain rare hardware failure cases, such as hard drive failures. The time to recover an ext3 file system after an unclean system shutdown does not depend on the size of the file system or the number of files; rather, it depends on the size of the *journal* used to maintain consistency. The default journal size takes about a second to recover, depending on the speed of the hardware.



Note

The only journaling mode in ext3 supported by Red Hat is **data=ordered** (default).

Data Integrity

The ext3 file system prevents loss of data integrity in the event that an unclean system shutdown occurs. The ext3 file system allows you to choose the type and level of protection that your data receives. With regard to the state of the file system, ext3 volumes are configured to keep a high level of data consistency by default.

Speed

Despite writing some data more than once, ext3 has a higher throughput in most cases than ext2 because ext3's journaling optimizes hard drive head motion. You can choose from three journaling modes to optimize speed, but doing so means trade-offs in regards to data integrity if the system was to fail.

Note

The only journaling mode in ext3 supported by Red Hat is **data=ordered** (default).

Easy Transition

It is easy to migrate from ext2 to ext3 and gain the benefits of a robust journaling file system without reformatting. Refer to Section 4.2, "Converting to an Ext3 File System" for more information on how to perform this task.

Note

Red Hat Enterprise Linux 7 provides a unified extN driver. It does this by disabling the ext2 and ext3 configurations and instead uses **ext4.ko** for these on-disk formats. This means that kernel messages will always refer to ext4 regardless of the ext file system used.

The following sections cover creating and tuning ext3 partitions. For ext2 partitions, skip the partitioning and formatting sections below and go directly to Section 4.2, "Converting to an Ext3 File System".

4.1. Creating an Ext3 File System

After installation, it is sometimes necessary to create a new ext3 file system. For example, if a new disk drive is added to the system, you may want to partition the drive and use the ext3 file system.

The steps for creating an ext3 file system are as follows:

Procedure 4.1. Create an ext3 file system

1. Format the partition or LVM volume with the ext3 file system using **mkfs**.
2. Label the file system using **e2label**.

It is also possible to add a specific UUID to a file system. For example, to add the UUID 7cd65de3-e0be-41d9-b66d-96d749c02da7 to the file system **/dev/sda8**, use the following commands:

```
# mkfs -t ext3 -U 7cd65de3-e0be-41d9-b66d-96d749c02da7 /dev/sda8
# tune2fs -U 7cd65de3-e0be-41d9-b66d-96d749c02da7 /dev/sda8
```

Replace the ext3 with the file system type you are using (ext4, for example), followed by the -U option with your chosen UUID, and replace the /dev/sda8 with the file system to have the UUID added to it.

4.2. Converting to an Ext3 File System

The **tune2fs** command converts an **ext2** file system to **ext3**.

Note

To convert ext2 to ext3, always use the **e2fsck** utility to check your file system before and after using **tune2fs**. Before trying to convert ext2 to ext3, back up all file systems in case any errors occur.

In addition, Red Hat recommends creating a new ext3 file system and migrating data to it, instead of converting from ext2 to ext3 whenever possible.

To convert an **ext2** file system to **ext3**, log in as root and type the following command in a terminal:

```
# tune2fs -j block_device
```

block_device contains the ext2 file system to be converted.

Issue the **df** command to display mounted file systems.

4.3. Reverting to an Ext2 File System

In order to revert to an ext2 file system, use the following procedure.

For simplicity, the sample commands in this section use the following value for the block device:

/dev/mapper/VolGroup00-LogVol02

Procedure 4.2. Revert from ext3 to ext2

1. Unmount the partition by logging in as root and typing:

   ```
   # umount /dev/mapper/VolGroup00-LogVol02
   ```

2. Change the file system type to ext2 by typing the following command:

   ```
   # tune2fs -O ^has_journal /dev/mapper/VolGroup00-LogVol02
   ```

3. Check the partition for errors by typing the following command:

   ```
   # e2fsck -y /dev/mapper/VolGroup00-LogVol02
   ```

4. Then mount the partition again as ext2 file system by typing:

   ```
   # mount -t ext2 /dev/mapper/VolGroup00-LogVol02 /mount/point
   ```

   In the above command, replace */mount/point* with the mount point of the partition.

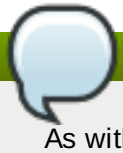
Note

If a **.journal** file exists at the root level of the partition, delete it.

To permanently change the partition to ext2, remember to update the **/etc/fstab** file, otherwise it will revert back after booting.

Chapter 5. The Ext4 File System

The ext4 file system is a scalable extension of the ext3 file system. With Red Hat Enterprise Linux 7, it can support a maximum individual file size of 16 terabytes, and file systems to a maximum of 50 terabytes, unlike Red Hat Enterprise Linux 6 which only supported file systems up to 16 terabytes. It also supports an unlimited number of sub-directories (the ext3 file system only supports up to 32,000), though once the link count exceeds 65,000 it resets to 1 and is no longer increased. The bigalloc feature is not currently supported.



Note

As with ext3, an ext4 volume must be umounted in order to perform an **fsck**. For more information, see Chapter 4, *The Ext3 File System*.

Main Features

Ext4 uses extents (as opposed to the traditional block mapping scheme used by ext2 and ext3), which improves performance when using large files and reduces metadata overhead for large files. In addition, ext4 also labels unallocated block groups and inode table sections accordingly, which allows them to be skipped during a file system check. This makes for quicker file system checks, which becomes more beneficial as the file system grows in size.

Allocation Features

The ext4 file system features the following allocation schemes:

- Persistent pre-allocation
- Delayed allocation
- Multi-block allocation
- Stripe-aware allocation

Because of delayed allocation and other performance optimizations, ext4's behavior of writing files to disk is different from ext3. In ext4, when a program writes to the file system, it is not guaranteed to be on-disk unless the program issues an **fsync()** call afterwards.

By default, ext3 automatically forces newly created files to disk almost immediately even without **fsync()**. This behavior hid bugs in programs that did not use **fsync()** to ensure that written data was on-disk. The ext4 file system, on the other hand, often waits several seconds to write out changes to disk, allowing it to combine and reorder writes for better disk performance than ext3.

Warning

Unlike ext3, the ext4 file system does not force data to disk on transaction commit. As such, it takes longer for buffered writes to be flushed to disk. As with any file system, use data integrity calls such as **fsync()** to ensure that data is written to permanent storage.

Other Ext4 Features

The ext4 file system also supports the following:

- *Extended attributes* (**xattr**) — This allows the system to associate several additional name and value pairs per file.
- *Quota journaling* — This avoids the need for lengthy quota consistency checks after a crash.

Note

The only supported journaling mode in ext4 is **data=ordered** (default).

- *Subsecond timestamps* — This gives timestamps to the subsecond.

5.1. Creating an Ext4 File System

To create an ext4 file system, use the **mkfs.ext4** command. In general, the default options are optimal for most usage scenarios:

```
# mkfs.ext4 /dev/device
```

Below is a sample output of this command, which displays the resulting file system geometry and features:

Example 5.1. mkfs.ext4 command output

```
~]# mkfs.ext4 /dev/sdb1
mke2fs 1.41.12 (17-May-2010)
Filesystem label=
OS type: Linux
Block size=4096 (log=2)
Fragment size=4096 (log=2)
Stride=0 blocks, Stripe width=0 blocks
245280 inodes, 979456 blocks
48972 blocks (5.00%) reserved for the super user
First data block=0
Maximum filesystem blocks=1006632960
30 block groups
32768 blocks per group, 32768 fragments per group
8176 inodes per group
Superblock backups stored on blocks:
 32768, 98304, 163840, 229376, 294912, 819200, 884736

Writing inode tables: done
Creating journal (16384 blocks): done
Writing superblocks and filesystem accounting information: done
```

For striped block devices (for example, RAID5 arrays), the stripe geometry can be specified at the time of file system creation. Using proper stripe geometry greatly enhances the performance of an ext4 file system.

When creating file systems on LVM or MD volumes, **mkfs.ext4** chooses an optimal geometry. This may also be true on some hardware RAIDs which export geometry information to the operating system.

To specify stripe geometry, use the **-E** option of **mkfs.ext4** (that is, extended file system options) with the following sub-options:

stride=*value*

Specifies the RAID chunk size.

stripe-width=*value*

Specifies the number of data disks in a RAID device, or the number of stripe units in the stripe.

For both sub-options, ***value*** must be specified in file system block units. For example, to create a file system with a 64k stride (that is, 16 x 4096) on a 4k-block file system, use the following command:

```
# mkfs.ext4 -E stride=16,stripe-width=64 /dev/device
```

For more information about creating file systems, refer to **man mkfs.ext4**.

Important

It is possible to use **tune2fs** to enable some ext4 features on ext3 file systems, and to use the ext4 driver to mount an ext3 file system. These actions, however, are *not* supported in Red Hat Enterprise Linux 7, as they have not been fully tested. Because of this, Red Hat cannot guarantee consistent performance and predictable behavior for ext3 file systems converted or mounted in this way.

It is also possible to add a specific UUID to the file system. See Section 4.1, “Creating an Ext3 File System” for more information.

5.2. Mounting an Ext4 File System

An ext4 file system can be mounted with no extra options. For example:

```
# mount /dev/device /mount/point
```

The ext4 file system also supports several mount options to influence behavior. For example, the **acl** parameter enables access control lists, while the **user_xattr** parameter enables user extended attributes. To enable both options, use their respective parameters with **-o**, as in:

```
# mount -o acl,user_xattr /dev/device /mount/point
```

As with ext3, the option **data_err=abort** can be used to abort the journal if an error occures in file data.

```
# mount -o data_err=abort /dev/device /mount/point
```

The **tune2fs** utility also allows administrators to set default mount options in the file system superblock. For more information on this, refer to **man tune2fs**.

Write Barriers

By default, ext4 uses write barriers to ensure file system integrity even when power is lost to a device with write caches enabled. For devices without write caches, or with battery-backed write caches, disable barriers using the **nobarrier** option, as in:

```
# mount -o nobarrier /dev/device /mount/point
```

For more information about write barriers, refer to Chapter 22, *Write Barriers*.

Direct Access Technology Preview

Starting with Red Hat Enterprise Linux 7.3, **Direct Access** (DAX) provides, as a Technology Preview on the ext4 and XFS file systems, a means for an application to directly map persistent memory into its address space. To use DAX, a system must have some form of persistent memory available, usually in the form of one or more Non-Volatile Dual In-line Memory Modules (NVDIMMs), and a file system that supports DAX must be created on the NVDIMM(s). Also, the file system must be mounted with the **dax** mount option. Then, an **mmap** of a file on the dax-mounted file system results in a direct mapping of storage into the application's address space.

5.3. Resizing an Ext4 File System

Before growing an ext4 file system, ensure that the underlying block device is of an appropriate size to hold the file system later. Use the appropriate resizing methods for the affected block device.

An ext4 file system may be grown while mounted using the **resize2fs** command:

```
# resize2fs /mount/device size
```

The **resize2fs** command can also decrease the size of an *unmounted* ext4 file system:

```
# resize2fs /dev/device size
```

When resizing an ext4 file system, the **resize2fs** utility reads the size in units of file system block size, unless a suffix indicating a specific unit is used. The following suffixes indicate specific units:

- **s** — 512 byte sectors
- **K** — kilobytes
- **M** — megabytes
- **G** — gigabytes

Note

The size parameter is optional (and often redundant) when expanding. The **resize2fs** automatically expands to fill all available space of the container, usually a logical volume or partition.

For more information about resizing an ext4 file system, refer to **man resize2fs**.

5.4. Backup ext2/3/4 File Systems

Procedure 5.1. Backup ext2/3/4 File Systems Example

1. All data must be backed up before attempting any kind of restore operation. Data backups should be made on a regular basis. In addition to data, there is configuration information that should be saved, including **/etc/fstab** and the output of **fdisk -l**. Running an sosreport/sysreport will capture this information and is strongly recommended.

```
# cat /etc/fstab
LABEL=/             /               ext3    defaults        1 1
LABEL=/boot1        /boot           ext3    defaults        1 2
LABEL=/data         /data           ext3    defaults        0 0
tmpfs               /dev/shm        tmpfs   defaults        0 0
devpts              /dev/pts        devpts  gid=5,mode=620  0 0
sysfs               /sys            sysfs   defaults        0 0
proc                /proc           proc    defaults        0 0
LABEL=SWAP-sda5     swap            swap    defaults        0 0
/dev/sda6           /backup-files   ext3    defaults        0 0

# fdisk -l
   Device Boot    Start       End    Blocks      Id  System
/dev/sda1 *           1        13    104391      83  Linux
/dev/sda2            14      1925   15358140    83  Linux
/dev/sda3          1926      3200   10241437+   83  Linux
/dev/sda4          3201      4864   13366080    5   Extended
/dev/sda5          3201      3391   1534176     82  Linux swap /
Solaris
/dev/sda6          3392      4864   11831841    83  Linux
```

   In this example, we will use the **/dev/sda6** partition to save backup files, and we assume that **/dev/sda6** is mounted on **/backup-files**.

2. If the partition being backed up is an operating system partition, bootup your system into Single User Mode. This step is not necessary for normal data partitions.

3. Use **dump** to backup the contents of the partitions:

Note

- If the system has been running for a long time, it is advisable to run **e2fsck** on the partitions before backup.
- **dump** should not be used on heavily loaded and mounted filesystem as it could backup corrupted version of files. This problem has been mentioned on dump.sourceforge.net.

Important

When backing up operating system partitions, the partition must be unmounted.

While it is possible to back up an ordinary data partition while it is mounted, it is adviseable to unmount it where possible. The results of attempting to back up a mounted data partition can be unpredicteable.

```
# dump -0uf /backup-files/sda1.dump /dev/sda1
# dump -0uf /backup-files/sda2.dump /dev/sda2
# dump -0uf /backup-files/sda3.dump /dev/sda3
```

If you want to do a remote backup, you can use both ssh or configure a non-password login.

Note

If using standard redirection, the '-f' option must be passed separately.

```
# dump -0u -f - /dev/sda1 | ssh root@remoteserver.example.com dd
of=/tmp/sda1.dump
```

5.5. Restore an ext2/3/4 File System

Procedure 5.2. Restore an ext2/3/4 File System Example

1. If you are restoring an operating system partition, bootup your system into Rescue Mode. This step is not required for ordinary data partitions.
2. Rebuild sda1/sda2/sda3/sda4/sda5 by using the **fdisk** command.

Note

If necessary, create the partitions to contain the restored file systems. The new partitions must be large enough to contain the restored data. It is important to get the start and end numbers right; these are the starting and ending sector numbers of the partitions.

3. Format the destination partitions by using the **mkfs** command, as shown below.

Important

DO NOT format **/dev/sda6** in the above example because it saves backup files.

```
# mkfs.ext3 /dev/sda1
# mkfs.ext3 /dev/sda2
# mkfs.ext3 /dev/sda3
```

4. If creating new partitions, re-label all the partitions so they match the **fstab** file. This step is not required if the partitions are not being recreated.

```
# e2label /dev/sda1 /boot1
# e2label /dev/sda2 /
# e2label /dev/sda3 /data
# mkswap -L SWAP-sda5 /dev/sda5
```

5. Prepare the working directories.

```
# mkdir /mnt/sda1
# mount -t ext3 /dev/sda1 /mnt/sda1
# mkdir /mnt/sda2
# mount -t ext3 /dev/sda2 /mnt/sda2
# mkdir /mnt/sda3
# mount -t ext3 /dev/sda3 /mnt/sda3
# mkdir /backup-files
# mount -t ext3 /dev/sda6 /backup-files
```

6. Restore the data.

```
# cd /mnt/sda1
# restore -rf /backup-files/sda1.dump
# cd /mnt/sda2
# restore -rf /backup-files/sda2.dump
# cd /mnt/sda3
# restore -rf /backup-files/sda3.dump
```

If you want to restore from a remote host or restore from a backup file on a remote host you can use either ssh or rsh. You will need to configure a password-less login for the following examples:

Login into 10.0.0.87, and restore sda1 from local sda1.dump file:

```
# ssh 10.0.0.87 "cd /mnt/sda1 && cat /backup-files/sda1.dump |
restore -rf -"
```

Login into 10.0.0.87, and restore sda1 from a remote 10.66.0.124 sda1.dump file:

```
# ssh 10.0.0.87 "cd /mnt/sda1 && RSH=/usr/bin/ssh restore -r -f
10.66.0.124:/tmp/sda1.dump"
```

7. Reboot.

5.6. Other Ext4 File System Utilities

Red Hat Enterprise Linux 7 also features other utilities for managing ext4 file systems:

e2fsck

Used to repair an ext4 file system. This tool checks and repairs an ext4 file system more efficiently than ext3, thanks to updates in the ext4 disk structure.

e2label

Changes the label on an ext4 file system. This tool also works on ext2 and ext3 file systems.

quota

Controls and reports on disk space (blocks) and file (inode) usage by users and groups on an ext4 file system. For more information on using **quota**, refer to **man quota** and Section 16.1, “Configuring Disk Quotas”.

fsfreeze

To suspend access to a file system, use the command **# fsfreeze -f *mount-point*** to freeze it and **# fsfreeze -u *mount-point*** to unfreeze it. This halts access to the file system and creates a stable image on disk.

Note

It is unnecessary to use **fsfreeze** for device-mapper drives.

For more information see the **fsfreeze(8)** manpage.

As demonstrated in Section 5.2, “Mounting an Ext4 File System”, the **tune2fs** utility can also adjust configurable file system parameters for ext2, ext3, and ext4 file systems. In addition, the following tools are also useful in debugging and analyzing ext4 file systems:

debugfs

Debugs ext2, ext3, or ext4 file systems.

e2image

Saves critical ext2, ext3, or ext4 file system metadata to a file.

For more information about these utilities, refer to their respective **man** pages.

Chapter 6. The XFS File System

XFS is a highly scalable, high-performance file system which was originally designed at Silicon Graphics, Inc. XFS is the default file system for Red Hat Enterprise Linux 7.

Main Features

XFS supports *metadata journaling*, which facilitates quicker crash recovery. The XFS file system can also be defragmented and enlarged while mounted and active. In addition, Red Hat Enterprise Linux 7 supports backup and restore utilities specific to XFS.

Allocation Features

XFS features the following allocation schemes:

- Extent-based allocation
- Stripe-aware allocation policies
- Delayed allocation
- Space pre-allocation

Delayed allocation and other performance optimizations affect XFS the same way that they do ext4. Namely, a program's writes to an XFS file system are not guaranteed to be on-disk unless the program issues an **`fsync()`** call afterwards.

For more information on the implications of delayed allocation on a file system (ext4 and XFS), refer to *Allocation Features* in Chapter 5, *The Ext4 File System*.

Note

Creating or expanding files occasionally fails with an unexpected ENOSPC write failure even though the disk space appears to be sufficient. This is due to XFS's performance-oriented design. In practice, it does not become a problem since it only occurs if remaining space is only a few blocks.

Other XFS Features

The XFS file system also supports the following:

***Extended attributes* (`xattr`)**

This allows the system to associate several additional name/value pairs per file. It is enabled by default.

Quota journaling

This avoids the need for lengthy quota consistency checks after a crash.

Project/directory quotas

This allows quota restrictions over a directory tree.

Subsecond timestamps

This allows timestamps to go to the subsecond.

Default atime behavior is relatime

Relatime is on by default for XFS. It has almost no overhead compared to **noatime** while still maintaining sane **atime** values.

6.1. Creating an XFS File System

To create an XFS file system, use the **mkfs.xfs /dev/*device*** command. In general, the default options are optimal for common use.

When using **mkfs.xfs** on a block device containing an existing file system, use the **-f** option to force an overwrite of that file system.

Example 6.1. mkfs.xfs command output

Below is a sample output of the **mkfs.xfs** command:

```
meta-data=/dev/device            isize=256    agcount=4, agsize=3277258
blks
         =                       sectsz=512   attr=2
data     =                       bsize=4096   blocks=13109032,
imaxpct=25
         =                       sunit=0      swidth=0 blks
naming   =version 2              bsize=4096   ascii-ci=0
log      =internal log           bsize=4096   blocks=6400, version=2
         =                       sectsz=512   sunit=0 blks, lazy-
count=1
realtime =none                   extsz=4096   blocks=0, rtextents=0
```

Note

After an XFS file system is created, its size cannot be reduced. However, it can still be enlarged using the **xfs_growfs** command (refer to Section 6.4, “Increasing the Size of an XFS File System”).

For striped block devices (for example, RAID5 arrays), the stripe geometry can be specified at the time of file system creation. Using proper stripe geometry greatly enhances the performance of an XFS filesystem.

When creating filesystems on LVM or MD volumes, **mkfs.xfs** chooses an optimal geometry. This may also be true on some hardware RAIDs that export geometry information to the operating system.

If the device exports stripe geometry information, **mkfs** (for ext3, ext4, and xfs) will automatically use this geometry. If stripe geometry is not detected by mkfs and even though the storage does, in fact, have stripe geometry, it is possible to manually specify it at mkfs time using the following options:

su=*value*

Specifies a stripe unit or RAID chunk size. The ***value*** must be specified in bytes, with an optional **k**, **m**, or **g** suffix.

sw=*value*

Specifies the number of data disks in a RAID device, or the number of stripe units in the stripe.

The following example specifies a chunk size of 64k on a RAID device containing 4 stripe units:

```
# mkfs.xfs -d su=64k,sw=4 /dev/device
```

For more information about creating XFS file systems, refer to **man mkfs.xfs** and the *Red Hat Enterprise Linux Performance Tuning Guide*, chapter *Basic Tuning for XFS*.

6.2. Mounting an XFS File System

An XFS file system can be mounted with no extra options, for example:

```
# mount /dev/device /mount/point
```

The default for Red Hat Enterprise Linux 7 is inode64.

Note

Unlike mke2fs, mkfs.xfs does not utilize a configuration file; they are all specified on the command line.

Write Barriers

By default, XFS uses write barriers to ensure file system integrity even when power is lost to a device with write caches enabled. For devices without write caches, or with battery-backed write caches, disable the barriers by using the **nobarrier** option:

```
# mount -o nobarrier /dev/device /mount/point
```

For more information about write barriers, refer to Chapter 22, *Write Barriers*.

Direct Access Technology Preview

Starting with Red Hat Enterprise Linux 7.3, **Direct Access** (DAX) provides, as a Technology Preview on the ext4 and XFS file systems, a means for an application to directly map persistent memory into its address space. To use DAX, a system must have some form of persistent memory available, usually in the form of one or more Non-Volatile Dual In-line Memory Modules (NVDIMMs), and a file system that supports DAX must be created on the NVDIMM(s). Also, the file system must be mounted with the **dax** mount option. Then, an **mmap** of a file on the dax-mounted file system results in a direct mapping of storage into the application's address space.

6.3. XFS Quota Management

The XFS quota subsystem manages limits on disk space (blocks) and file (inode) usage. XFS quotas control or report on usage of these items on a user, group, or directory or project level. Also, note that while user, group, and directory or project quotas are enabled independently, group and project quotas are mutually exclusive.

When managing on a per-directory or per-project basis, XFS manages the disk usage of directory hierarchies associated with a specific project. In doing so, XFS recognizes cross-organizational "group" boundaries between projects. This provides a level of control that is broader than what is available when managing quotas for users or groups.

XFS quotas are enabled at mount time, with specific mount options. Each mount option can also be specified as **noenforce**; this will allow usage reporting without enforcing any limits. Valid quota mount options are:

- **uquota**/**uqnoenforce** - User quotas
- **gquota**/**gqnoenforce** - Group quotas
- **pquota**/**pqnoenforce** - Project quota

Once quotas are enabled, the **xfs_quota** tool can be used to set limits and report on disk usage. By default, **xfs_quota** is run interactively, and in *basic mode*. Basic mode sub-commands simply report usage, and are available to all users. Basic **xfs_quota** sub-commands include:

quota ***username/userID***

Show usage and limits for the given ***username*** or numeric ***userID***

df

Shows free and used counts for blocks and inodes.

In contrast, **xfs_quota** also has an *expert mode*. The sub-commands of this mode allow actual configuration of limits, and are available only to users with elevated privileges. To use expert mode sub-commands interactively, run **xfs_quota -x**. Expert mode sub-commands include:

report ***/path***

Reports quota information for a specific file system.

limit

Modify quota limits.

For a complete list of sub-commands for either basic or expert mode, use the sub-command **help**.

All sub-commands can also be run directly from a command line using the **-c** option, with **-x** for expert sub-commands.

Example 6.2. Display a sample quota report

For example, to display a sample quota report for **/home** (on **/dev/blockdevice**), use the command **xfs_quota -x -c 'report -h' /home**. This will display output similar to the following:

```
User quota on /home (/dev/blockdevice)
                        Blocks
User ID      Used   Soft   Hard Warn/Grace
---------- ---------------------------------
root            0      0      0  00 [------]
testuser   103.4G      0      0  00 [------]
...
```

To set a soft and hard inode count limit of 500 and 700 respectively for user **john** (whose home directory is **/home/john**), use the following command:

```
# xfs_quota -x -c 'limit isoft=500 ihard=700 john' /home/
```

In this case, pass *mount_point* which is the mounted xfs file system.

By default, the **limit** sub-command recognizes targets as users. When configuring the limits for a group, use the **-g** option (as in the previous example). Similarly, use **-p** for projects.

Soft and hard block limits can also be configured using **bsoft** or **bhard** instead of **isoft** or **ihard**.

Example 6.3. Set a soft and hard block limit

For example, to set a soft and hard block limit of 1000m and 1200m, respectively, to group **accounting** on the **/target/path** file system, use the following command:

```
# xfs_quota -x -c 'limit -g bsoft=1000m bhard=1200m accounting'
/target/path
```

Note

The commands **bsoft** and **bhard** count by the byte.

Important

While real-time blocks (**rtbhard**/**rtbsoft**) are described in **man xfs_quota** as valid units when setting quotas, the real-time sub-volume is not enabled in this release. As such, the **rtbhard** and **rtbsoft** options are not applicable.

Setting Project Limits

Before configuring limits for project-controlled directories, add them first to **/etc/projects**. Project names can be added to **/etc/projectid** to map project IDs to project names. Once a project is added to **/etc/projects**, initialize its project directory using the following command:

```
# xfs_quota -x -c 'project -s projectname' project_path
```

Quotas for projects with initialized directories can then be configured, with:

```
# xfs_quota -x -c 'limit -p bsoft=1000m bhard=1200m projectname'
```

Generic quota configuration tools (**quota**, **repquota**, and **edquota** for example) may also be used to manipulate XFS quotas. However, these tools cannot be used with XFS project quotas.

Important

Red Hat recommends the use of **xfs_quota** over all other available tools.

For more information about setting XFS quotas, refer to **man xfs_quota**, **man projid(5)**, and **man projects(5)**.

6.4. Increasing the Size of an XFS File System

An XFS file system may be grown while mounted using the **xfs_growfs** command:

```
# xfs_growfs /mount/point -D size
```

The **-D *size*** option grows the file system to the specified ***size*** (expressed in file system blocks). Without the **-D *size*** option, **xfs_growfs** will grow the file system to the maximum size supported by the device.

Before growing an XFS file system with **-D *size***, ensure that the underlying block device is of an appropriate size to hold the file system later. Use the appropriate resizing methods for the affected block device.

Note

While XFS file systems can be grown while mounted, their size cannot be reduced at all.

For more information about growing a file system, refer to **man xfs_growfs**.

6.5. Repairing an XFS File System

To repair an XFS file system, use **xfs_repair**:

```
# xfs_repair /dev/device
```

The **xfs_repair** utility is highly scalable and is designed to repair even very large file systems with many inodes efficiently. Unlike other Linux file systems, **xfs_repair** does not run at boot time, even when an XFS file system was not cleanly unmounted. In the event of an unclean unmount, **xfs_repair** simply replays the log at mount time, ensuring a consistent file system.

Warning

The **xfs_repair** utility cannot repair an XFS file system with a dirty log. To clear the log, mount and unmount the XFS file system. If the log is corrupt and cannot be replayed, use the **-L** option ("force log zeroing") to clear the log, that is, **xfs_repair -L /dev/device**. Be aware that this may result in further corruption or data loss.

For more information about repairing an XFS file system, refer to **man xfs_repair**.

6.6. Suspending an XFS File System

To suspend or resume write activity to a file system, use **xfs_freeze**. Suspending write activity allows hardware-based device snapshots to be used to capture the file system in a consistent state.

Note

The **xfs_freeze** utility is provided by the **xfsprogs** package, which is only available on x86_64.

To suspend (that is, freeze) an XFS file system, use:

```
# xfs_freeze -f /mount/point
```

To unfreeze an XFS file system, use:

```
# xfs_freeze -u /mount/point
```

When taking an LVM snapshot, it is not necessary to use **xfs_freeze** to suspend the file system first. Rather, the LVM management tools will automatically suspend the XFS file system before taking the snapshot.

For more information about freezing and unfreezing an XFS file system, refer to **man xfs_freeze**.

6.7. Backup and Restoration of XFS File Systems

XFS file system backup and restoration involves two utilities: **xfsdump** and **xfsrestore**.

To backup or dump an XFS file system, use the **xfsdump** utility. Red Hat Enterprise Linux 7 supports backups to tape drives or regular file images, and also allows multiple dumps to be written to the same tape. The **xfsdump** utility also allows a dump to span multiple tapes, although only one dump can be written to a regular file. In addition, **xfsdump** supports incremental backups, and can exclude files from a backup using size, subtree, or inode flags to filter them.

In order to support incremental backups, **xfsdump** uses *dump levels* to determine a base dump to which a specific dump is relative. The **-l** option specifies a dump level (*0*-*9*). To perform a full backup, perform a *level 0* dump on the file system (that is, ***/path/to/filesystem***), as in:

```
# xfsdump -l 0 -f /dev/device /path/to/filesystem
```

Note

The **-f** option specifies a destination for a backup. For example, the **/dev/st0** destination is normally used for tape drives. An **xfsdump** destination can be a tape drive, regular file, or remote tape device.

In contrast, an incremental backup will only dump files that changed since the last *level 0* dump. A *level 1* dump is the first incremental dump after a full dump; the next incremental dump would be *level 2*, and so on, to a maximum of *level 9*. So, to perform a *level 1* dump to a tape drive:

```
# xfsdump -l 1 -f /dev/st0 /path/to/filesystem
```

Conversely, the **xfsrestore** utility restores file systems from dumps produced by **xfsdump**. The **xfsrestore** utility has two modes: a default *simple* mode, and a *cumulative* mode. Specific dumps are identified by *session ID* or *session label*. As such, restoring a dump requires its corresponding session ID or label. To display the session ID and labels of all dumps (both full and incremental), use the **-I** option:

```
# xfsrestore -I
```

This will provide output similar to the following:

Example 6.4. Session ID and labels of all dumps

```
file system 0:
 fs id:  45e9af35-efd2-4244-87bc-4762e476cbab
 session 0:
  mount point: bear-05:/mnt/test
  device:  bear-05:/dev/sdb2
  time:  Fri Feb 26 16:55:21 2010
  session label: "my_dump_session_label"
  session id: b74a3586-e52e-4a4a-8775-c3334fa8ea2c
  level:  0
  resumed: NO
  subtree: NO
  streams: 1
  stream 0:
   pathname: /mnt/test2/backup
   start:  ino 0 offset 0
   end:  ino 1 offset 0
   interrupted: NO
   media files: 1
   media file 0:
    mfile index: 0
    mfile type: data
    mfile size: 21016
    mfile start: ino 0 offset 0
    mfile end: ino 1 offset 0
    media label: "my_dump_media_label"
    media id: 4a518062-2a8f-4f17-81fd-bb1eb2e3cb4f
xfsrestore: Restore Status: SUCCESS
```

Simple Mode for xfsrestore

The *simple* mode allows users to restore an entire file system from a *level 0* dump. After identifying a *level 0* dump's session ID (that is, ***session-ID***), restore it fully to ***/path/to/destination*** using:

```
# xfsrestore -f /dev/st0 -S session-ID /path/to/destination
```

Note

The **-f** option specifies the location of the dump, while the **-S** or **-L** option specifies which specific dump to restore. The **-S** option is used to specify a session ID, while the **-L** option is used for session labels. The **-I** option displays both session labels and IDs for each dump.

Cumulative Mode for xfsrestore

The *cumulative* mode of **xfsrestore** allows file system restoration from a specific incremental backup, for example, *level 1* to *level 9*. To restore a file system from an incremental backup, simply add the **-r** option:

```
# xfsrestore -f /dev/st0 -S session-ID -r /path/to/destination
```

Interactive Operation

The **xfsrestore** utility also allows specific files from a dump to be extracted, added, or deleted. To use **xfsrestore** interactively, use the **-i** option, as in:

```
xfsrestore -f /dev/st0 -i /destination/directory
```

The interactive dialogue will begin after **xfsrestore** finishes reading the specified device. Available commands in this dialogue include **cd**, **ls**, **add**, **delete**, and **extract**; for a complete list of commands, use **help**.

For more information about dumping and restoring XFS file systems, refer to **man xfsdump** and **man xfsrestore**.

6.8. Other XFS File System Utilities

Red Hat Enterprise Linux 7 also features other utilities for managing XFS file systems:

xfs_fsr

Used to defragment mounted XFS file systems. When invoked with no arguments, **xfs_fsr** defragments all regular files in all mounted XFS file systems. This utility also allows users to suspend a defragmentation at a specified time and resume from where it left off later.

In addition, **xfs_fsr** also allows the defragmentation of only one file, as in **xfs_fsr** */path/to/file*. Red Hat advises not to periodically defrag an entire file system because XFS avoids fragmentation by default. System wide defragmentation could cause the side effect of fragmentation in free space.

xfs_bmap

Prints the map of disk blocks used by files in an XFS filesystem. This map lists each extent used by a specified file, as well as regions in the file with no corresponding blocks (that is, holes).

xfs_info

Prints XFS file system information.

xfs_admin

Changes the parameters of an XFS file system. The **xfs_admin** utility can only modify parameters of unmounted devices or file systems.

xfs_copy

Copies the contents of an entire XFS file system to one or more targets in parallel.

The following utilities are also useful in debugging and analyzing XFS file systems:

xfs_metadump

Copies XFS file system metadata to a file. Red Hat only supports using the **xfs_metadump** utility to copy unmounted file systems or read-only mounted file systems; otherwise, generated dumps could be corrupted or inconsistent.

xfs_mdrestore

Restores an XFS metadump image (generated using **xfs_metadump**) to a file system image.

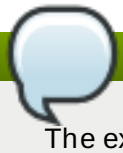
xfs_db

Debugs an XFS file system.

For more information about these utilities, refer to their respective **man** pages.

6.9. Migrating from ext4 to XFS

A major change in Red Hat Enterprise 7 is the switch from ext4 to XFS as the default filesystem. This section highlights the differences which may be enountered when using or administering an XFS filesystem.



Note

The ext4 file system is still fully supported in Red Hat Enterprise Linux 7 and may be selected at installation if desired. While it is possible to migrate from ext4 to XFS it is not required.

6.9.1. Ext3/4 commands and tools and their XFS counterparts

The following table shows common commands for ext3 and ext4, and their XFS-specific counterparts.

Table 6.1. Common Commands for ext3/4 and XFS

Task	ext3/4	XFS
Create a file system	**mkfs.ext4** or **mkfs.ext3**	**mkfs.xfs**
File system check	**e2fsck**	**xfs_repair**
Resizing a file system	**resize2fs**	**xfs_growfs**
Save an image of a file system	**e2image**	**xfs_metadump** and **xfs_mdrestore**
Label or tune a file system	**tune2fs**	**xfs_admin**
Backup a file system	**dump** and **restore**	**xfsdump** and **xfsrestore**

The following table shows generic tools that function on XFS file systems as well, but the XFS versions have more specific functionality and as such are recommended.

Table 6.2. Generic tools for ext2 and XFS

Task	ext4	XFS
Quota	**quota**	**xfs_quota**
File mapping	**filefrag**	**xfs_bmap**

Every XFS administrative tool has a complete man page and many of these commands are explained in further detail in Chapter 6, *The XFS File System*.

6.9.2. Behavioral and Administrative Differences Between Ext3/4 and XFS

File system repair

Ext3/4 runs **e2fsck** in userspace at boot time to recover the journal as needed. XFS, by comparison, performs journal recovery in kernelspace at mount time. An **fsck.xfs** shell script is provided but does not perform any useful action as it is only there to satisfy initscript requirements.

When an XFS file system repair or check is requested, use the **xfs_repair** command. Use the **-n** option for a read-only check.

The **xfs_repair** command will not operate on a file system with a dirty log. To repair such a file system **mount** and **unmount** must first be performed to replay the log. If the log is corrupt and cannot be replayed, the **-L** option can be used to zero out in the log.

For more information on file system repair of XFS file systems, refer to Section 11.2.2, “XFS”

Metadata error behavior

The ext3/4 file system has configurable behavior when metadata errors are encountered, with the default being to simply continue. When XFS encounters a metadata error that is not recoverable it will shut down the file system and return a **EFSCORRUPTED** error. The system logs will contain details of the error enountered and will recommend running **xfs_repair** if necessary.

Quotas

XFS quotas are not a remountable option. The **-o quota** option must be specified on the initial mount for quotas to be in effect.

While the standard tools in the quota package can perform basic quota administrative tasks (tools such as **setquota** and **repquota**), the **xfs_quota** tool can be used for XFS-specific features, such as Project Quota administration.

The **quotacheck** command has no effect on an XFS file system. The first time quota accounting is turned on XFS does an automatic **quotacheck** internally. Because XFS quota metadata is a first-class, journaled metadata object, the quota system will always be consistent until quotas are manually turned off.

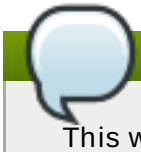
File system resize

The XFS file system has no utility to shrink a file system. XFS file systems can be grown online via the **xfs_growfs** command.

Inode numbers

For file systems above 1T with 256 byte inodes, or above 2T with 512 byte inodes, XFS

inode numbers may exceed 2^32. These large inode numbers will cause 32-bit stat calls to fail with **EOVERFLOW**. In general, applications should properly handle these larger inode numbers but, if necessary XFS may be mounted with **-o inode32** to enforce inode numbers below 2^32.



Note

This will not affect inodes already allocated with 64-bit numbers.

This option changes allocation behavior and may lead to early ENOSPC if no space is available to allocate inodes in the lower disk blocks. The inode32 option should not be used unless required by a specific environment.

Speculative preallocation

XFS uses *speculative preallocation* to allocate blocks past EOF as files are written. This avoids file fragmentation due to concurrent streaming write workloads on NFS servers. By default, this preallocation increases with the size of the file and will be apparent in "du" output. If a file with speculative preallocation is not dirtied for five minutes the preallocation will be discarded. If the inode is cycled out of cache before that time, then the preallocation will be discarded when the inode is reclaimed.

If premature ENOSPC problems are seen due to speculative preallocation, a fixed preallocation amount may be specified with the **-o allocsize=*amount*** mount option.

Fragmentation-related tools

Fragmentation is rarely a significant issue on XFS file systems due to heuristics and behaviors, such as delayed allocation and speculative preallocation. However, tools exist for measuring file system fragmentation as well as defragmenting file systems. Their use is not encouraged.

The **xfs_db frag** command attempts to distill all file system allocations into a single fragmentation number, expressed as a percentage. The output of the comand requires significant expertise to understand its meaning. For example, a fragmentation factor of 75% means only an average of 4 extents per file. For this reason the output of xfs_db's frag is not considered useful and more careful analysis of any fragmentation problems is recommended.

Warning

The **xfs_fsr** command may be used to defragment individual files, or all files on a file system. The later is especially not recommended as it may destroy locality of files and may fragment freespace.

Chapter 7. Global File System 2

The Red Hat Global File System 2 (GFS2) is a native file system that interfaces directly with the Linux kernel file system interface (VFS layer). When implemented as a cluster file system, GFS2 employs distributed metadata and multiple journals.

GFS2 is based on 64-bit architecture, which can theoretically accommodate an 8 exabyte file system. However, the current supported maximum size of a GFS2 file system is 100 TB. If a system requires GFS2 file systems larger than 100 TB, contact your Red Hat service representative.

When determining the size of a file system, consider its recovery needs. Running the **fsck** command on a very large file system can take a long time and consume a large amount of memory. Additionally, in the event of a disk or disk-subsystem failure, recovery time is limited by the speed of backup media.

When configured in a Red Hat Cluster Suite, Red Hat GFS2 nodes can be configured and managed with Red Hat Cluster Suite configuration and management tools. Red Hat GFS2 then provides data sharing among GFS2 nodes in a Red Hat cluster, with a single, consistent view of the file system name space across the GFS2 nodes. This allows processes on different nodes to share GFS2 files in the same way that processes on the same node can share files on a local file system, with no discernible difference. For information about the Red Hat Cluster Suite, refer to Red Hat's *Cluster Administration* guide.

A GFS2 must be built on a logical volume (created with LVM) that is a linear or mirrored volume. Logical volumes created with LVM in a Red Hat Cluster suite are managed with CLVM (a cluster-wide implementation of LVM), enabled by the CLVM daemon **clvmd**, and running in a Red Hat Cluster Suite cluster. The daemon makes it possible to use LVM2 to manage logical volumes across a cluster, allowing all nodes in the cluster to share the logical volumes. For information on the Logical Volume Manager, see Red Hat's *Logical Volume Manager Administration* guide.

The **gfs2.ko** kernel module implements the GFS2 file system and is loaded on GFS2 cluster nodes.

For comprehensive information on the creation and configuration of GFS2 file systems in clustered and non-clustered storage, refer to Red Hat's *Global File System 2* guide.

Chapter 8. Network File System (NFS)

A *Network File System* (*NFS*) allows remote hosts to mount file systems over a network and interact with those file systems as though they are mounted locally. This enables system administrators to consolidate resources onto centralized servers on the network.

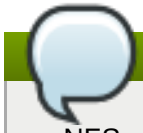
This chapter focuses on fundamental NFS concepts and supplemental information.

8.1. How NFS Works

Currently, there are two major versions of NFS included in Red Hat Enterprise Linux. NFS version 3 (NFSv3) supports safe asynchronous writes and is more robust at error handling than the previous NFSv2; it also supports 64-bit file sizes and offsets, allowing clients to access more than 2 GB of file data. NFSv4 works through firewalls and on the Internet, no longer requires an **rpcbind** service, supports ACLs, and utilizes stateful operations.

Red Hat Enterprise Linux 7 adds support for NFS version 4.1 (NFSv4.1), which provides a number of performance and security enhancements, including client-side support for Parallel NFS (pNFS). NFSv4.1 no longer requires a separate TCP connection for callbacks, which allows an NFS server to grant delegations even when it cannot contact the client (for example, when NAT or a firewall interferes). Additionally, NFSv4.1 now provides true exactly-once semantics (except for reboot operations), preventing a previous issue whereby certain operations could return an inaccurate result if a reply was lost and the operation was sent twice.

Red Hat Enterprise Linux 7 supports NFSv3, NFSv4.0, and NVSv4.1 clients. NFS clients attempt to mount using NFSv4.0 by default, and fall back to NFSv3 if the mount operation is not successful.



Note

NFS version 2 (NFSv2) is no longer supported by Red Hat.

All versions of NFS can use *Transmission Control Protocol* (*TCP*) running over an IP network, with NFSv4 requiring it. NFSv3 can use the *User Datagram Protocol* (UDP) running over an IP network to provide a stateless network connection between the client and server.

When using NFSv3 with UDP, the stateless UDP connection (under normal conditions) has less protocol overhead than TCP. This can translate into better performance on very clean, non-congested networks. However, because UDP is stateless, if the server goes down unexpectedly, UDP clients continue to saturate the network with requests for the server. In addition, when a frame is lost with UDP, the entire RPC request must be retransmitted; with TCP, only the lost frame needs to be resent. For these reasons, TCP is the preferred protocol when connecting to an NFS server.

The mounting and locking protocols have been incorporated into the NFSv4 protocol. The server also listens on the well-known TCP port 2049. As such, NFSv4 does not need to interact with **rpcbind** [1], **lockd**, and **rpc.statd** daemons. The **rpc.mountd** daemon is still required on the NFS server to set up the exports, but is not involved in any over-the-wire operations.

Note

TCP is the default transport protocol for NFS version 2 and 3 under Red Hat Enterprise Linux. UDP can be used for compatibility purposes as needed, but is not recommended for wide usage. NFSv4 requires TCP.

All the RPC/NFS daemons have a **'-p'** command line option that can set the port, making firewall configuration easier.

After TCP wrappers grant access to the client, the NFS server refers to the **/etc/exports** configuration file to determine whether the client is allowed to access any exported file systems. Once verified, all file and directory operations are available to the user.

Important

In order for NFS to work with a default installation of Red Hat Enterprise Linux with a firewall enabled, configure IPTables with the default TCP port 2049. Without proper IPTables configuration, NFS will not function properly.

The NFS initialization script and **rpc.nfsd** process now allow binding to any specified port during system start up. However, this can be error-prone if the port is unavailable, or if it conflicts with another daemon.

8.1.1. Required Services

Red Hat Enterprise Linux uses a combination of kernel-level support and daemon processes to provide NFS file sharing. All NFS versions rely on *Remote Procedure Calls* (*RPC*) between clients and servers. RPC services under Red Hat Enterprise Linux 7 are controlled by the **rpcbind** service. To share or mount NFS file systems, the following services work together depending on which version of NFS is implemented:

Note

The **portmap** service was used to map RPC program numbers to IP address port number combinations in earlier versions of Red Hat Enterprise Linux. This service is now replaced by **rpcbind** in Red Hat Enterprise Linux 7 to enable IPv6 support. For more information about this change, refer to the following links:

- *TI-RPC / rpcbind support*: http://nfsv4.bullopensource.org/doc/tirpc_rpcbind.php
- *IPv6 support in NFS*: http://nfsv4.bullopensource.org/doc/nfs_ipv6.php

nfs

systemctl start nfs starts the NFS server and the appropriate RPC processes to service requests for shared NFS file systems.

nfslock

systemctl start nfs-lock activates a mandatory service that starts the appropriate

RPC processes allowing NFS clients to lock files on the server.

rpcbind

rpcbind accepts port reservations from local RPC services. These ports are then made available (or advertised) so the corresponding remote RPC services can access them. **rpcbind** responds to requests for RPC services and sets up connections to the requested RPC service. This is not used with NFSv4.

The following RPC processes facilitate NFS services:

rpc.mountd

This process is used by an NFS server to process **MOUNT** requests from NFSv3 clients. It checks that the requested NFS share is currently exported by the NFS server, and that the client is allowed to access it. If the mount request is allowed, the rpc.mountd server replies with a **Success** status and provides the **File-Handle** for this NFS share back to the NFS client.

rpc.nfsd

rpc.nfsd allows explicit NFS versions and protocols the server advertises to be defined. It works with the Linux kernel to meet the dynamic demands of NFS clients, such as providing server threads each time an NFS client connects. This process corresponds to the **nfs** service.

lockd

lockd is a kernel thread which runs on both clients and servers. It implements the *Network Lock Manager* (NLM) protocol, which allows NFSv3 clients to lock files on the server. It is started automatically whenever the NFS server is run and whenever an NFS file system is mounted.

rpc.statd

This process implements the *Network Status Monitor* (NSM) RPC protocol, which notifies NFS clients when an NFS server is restarted without being gracefully brought down. **rpc.statd** is started automatically by the **nfslock** service, and does not require user configuration. This is not used with NFSv4.

rpc.rquotad

This process provides user quota information for remote users. **rpc.rquotad** is started automatically by the **nfs** service and does not require user configuration.

rpc.idmapd

rpc.idmapd provides NFSv4 client and server upcalls, which map between on-the-wire NFSv4 names (strings in the form of ***user*@*domain***) and local UIDs and GIDs. For **idmapd** to function with NFSv4, the **/etc/idmapd.conf** file must be configured. At a minimum, the "Domain" parameter should be specified, which defines the NFSv4 mapping domain. If the NFSv4 mapping domain is the same as the DNS domain name, this parameter can be skipped. The client and server must agree on the NFSv4 mapping domain for ID mapping to function properly.

Note

In Red Hat Enterprise Linux 7, only the NFSv4 server uses **rpc.idmapd**. The NFSv4 client uses the keyring-based idmapper **nfsidmap**. **nfsidmap** is a stand-alone program that is called by the kernel on-demand to perform ID mapping; it is not a daemon. If there is a problem with **nfsidmap** does the client fall back to using **rpc.idmapd**. More information regarding **nfsidmap** can be found on the nfsidmap man page.

8.2. pNFS

Support for Parallel NFS (pNFS) as part of the NFS v4.1 standard is available as of Red Hat Enterprise Linux 6.4. The pNFS architecture improves the scalability of NFS, with possible improvements to performance. That is, when a server implements pNFS as well, a client is able to access data through multiple servers concurrently. It supports three storage protocols or layouts: files, objects, and blocks.

Note

The protocol allows for three possible pNFS layout types: files, objects, and blocks. While the Red Hat Enterprise Linux 6.4 client only supported the files layout type, Red Hat Enterprise Linux 7 supports the files layout type, with objects and blocks layout types being included as a technology preview.

To enable this functionality, use the following mount option on mounts from a pNFS-enabled server:

```
-o v4.1
```

After the server is pNFS-enabled, the **nfs_layout_nfsv41_files** kernel is automatically loaded on the first mount. The mount entry in the output should contain **minorversion=1**. Use the following command to verify the module was loaded:

```
$ lsmod | grep nfs_layout_nfsv41_files
```

For more information on pNFS, refer to: http://www.pnfs.com.

8.3. NFS Client Configuration

The **mount** command mounts NFS shares on the client side. Its format is as follows:

```
# mount -t nfs -o options server:/remote/export /local/directory
```

This command uses the following variables:

options

A comma-delimited list of mount options; refer to Section 8.5, “Common NFS Mount Options” for details on valid NFS mount options.

server

The hostname, IP address, or fully qualified domain name of the server exporting the file system you wish to mount

/remote/export

The file system or directory being exported from the *server*, that is, the directory you wish to mount

/local/directory

The client location where */remote/export* is mounted

The NFS protocol version used in Red Hat Enterprise Linux 7 is identified by the **mount** options **nfsvers** or **vers**. By default, **mount** will use NFSv4 with **mount -t nfs**. If the server does not support NFSv4, the client will automatically step down to a version supported by the server. If the **nfsvers**/**vers** option is used to pass a particular version not supported by the server, the mount will fail. The file system type nfs4 is also available for legacy reasons; this is equivalent to running **mount -t nfs -o nfsvers=4 *host*:*/remote/export /local/directory***.

Refer to **man mount** for more details.

If an NFS share was mounted manually, the share will not be automatically mounted upon reboot. Red Hat Enterprise Linux offers two methods for mounting remote file systems automatically at boot time: the **/etc/fstab** file and the **autofs** service. Refer to Section 8.3.1, “Mounting NFS File Systems using **/etc/fstab**” and Section 8.4, “**autofs**” for more information.

8.3.1. Mounting NFS File Systems using `/etc/fstab`

An alternate way to mount an NFS share from another machine is to add a line to the **/etc/fstab** file. The line must state the hostname of the NFS server, the directory on the server being exported, and the directory on the local machine where the NFS share is to be mounted. You must be root to modify the **/etc/fstab** file.

Example 8.1. Syntax example

The general syntax for the line in **/etc/fstab** is as follows:

```
server:/usr/local/pub    /pub    nfs    defaults 0 0
```

The mount point **/pub** must exist on the client machine before this command can be executed. After adding this line to **/etc/fstab** on the client system, use the command **mount /pub**, and the mount point **/pub** is mounted from the server.

A valid **/etc/fstab** entry to mount an NFS export should contain the following information:

```
server:/remote/export /local/directory nfs options 0 0
```

The variables *server*, */remote/export*, */local/directory*, and *options* are the same ones used when manually mounting an NFS share. Refer to Section 8.3, “NFS Client Configuration” for a definition of each variable.

Note

The mount point */local/directory* must exist on the client before **/etc/fstab** is read. Otherwise, the mount will fail.

For more information about **/etc/fstab**, refer to **man fstab**.

8.4. autofs

One drawback to using **/etc/fstab** is that, regardless of how infrequently a user accesses the NFS mounted file system, the system must dedicate resources to keep the mounted file system in place. This is not a problem with one or two mounts, but when the system is maintaining mounts to many systems at one time, overall system performance can be affected. An alternative to **/etc/fstab** is to use the kernel-based **automount** utility. An automounter consists of two components:

- a kernel module that implements a file system, and
- a user-space daemon that performs all of the other functions.

The **automount** utility can mount and unmount NFS file systems automatically (on-demand mounting), therefore saving system resources. It can be used to mount other file systems including AFS, SMBFS, CIFS, and local file systems.

Important

The nfs-utils package is now a part of both the 'NFS file server' and the 'Network File System Client' groups. As such, it is no longer installed by default with the Base group. Ensure that nfs-utils is installed on the system first before attempting to automount an NFS share.

autofs is also part of the 'Network File System Client' group.

autofs uses **/etc/auto.master** (master map) as its default primary configuration file. This can be changed to use another supported network source and name using the **autofs** configuration (in **/etc/sysconfig/autofs**) in conjunction with the Name Service Switch (NSS) mechanism. An instance of the **autofs** version 4 daemon was run for each mount point configured in the master map and so it could be run manually from the command line for any given mount point. This is not possible with **autofs** version 5, because it uses a single daemon to manage all configured mount points; as such, all automounts must be configured in the master map. This is in line with the usual requirements of other industry standard automounters. Mount point, hostname, exported directory, and options can all be specified in a set of files (or other supported network sources) rather than configuring them manually for each host.

8.4.1. Improvements in autofs Version 5 over Version 4

autofs version 5 features the following enhancements over version 4:

Direct map support

Direct maps in **autofs** provide a mechanism to automatically mount file systems at arbitrary points in the file system hierarchy. A direct map is denoted by a mount point of **/-** in the master map. Entries in a direct map contain an absolute path name as a key (instead of the relative path names used in indirect maps).

Lazy mount and unmount support

Multi-mount map entries describe a hierarchy of mount points under a single key. A good example of this is the **-hosts** map, commonly used for automounting all exports from a host under **/net/*host*** as a multi-mount map entry. When using the **-hosts** map, an **ls** of **/net/*host*** will mount *autofs* trigger mounts for each export from *host*. These will then mount and expire them as they are accessed. This can greatly reduce the number of active mounts needed when accessing a server with a large number of exports.

Enhanced LDAP support

The **autofs** configuration file (**/etc/sysconfig/autofs**) provides a mechanism to specify the **autofs** schema that a site implements, thus precluding the need to determine this via trial and error in the application itself. In addition, authenticated binds to the LDAP server are now supported, using most mechanisms supported by the common LDAP server implementations. A new configuration file has been added for this support: **/etc/autofs_ldap_auth.conf**. The default configuration file is self-documenting, and uses an XML format.

Proper use of the Name Service Switch (nsswitch) configuration.

The Name Service Switch configuration file exists to provide a means of determining from where specific configuration data comes. The reason for this configuration is to allow administrators the flexibility of using the back-end database of choice, while maintaining a uniform software interface to access the data. While the version 4 automounter is becoming increasingly better at handling the NSS configuration, it is still not complete. Autofs version 5, on the other hand, is a complete implementation.

Refer to **man nsswitch.conf** for more information on the supported syntax of this file. Not all NSS databases are valid map sources and the parser will reject ones that are invalid. Valid sources are files, **yp**, **nis**, **nisplus**, **ldap**, and **hesiod**.

Multiple master map entries per autofs mount point

One thing that is frequently used but not yet mentioned is the handling of multiple master map entries for the direct mount point **/-**. The map keys for each entry are merged and behave as one map.

Example 8.2. Multiple master map entries per autofs mount point

An example is seen in the connectathon test maps for the direct mounts below:

```
/- /tmp/auto_dcthon
/- /tmp/auto_test3_direct
/- /tmp/auto_test4_direct
```

8.4.2. autofs Configuration

The primary configuration file for the automounter is **/etc/auto.master**, also referred to as the

master map which may be changed as described in the Section 8.4.1, “Improvements in autofs Version 5 over Version 4”. The master map lists **autofs**-controlled mount points on the system, and their corresponding configuration files or network sources known as automount maps. The format of the master map is as follows:

```
mount-point map-name options
```

The variables used in this format are:

mount-point

The **autofs** mount point, **/home**, for example.

map-name

The name of a map source which contains a list of mount points, and the file system location from which those mount points should be mounted. The syntax for a map entry is described below.

options

If supplied, these will apply to all entries in the given map provided they don't themselves have options specified. This behavior is different from **autofs** version 4 where options were cumulative. This has been changed to implement mixed environment compatibility.

Example 8.3. /etc/auto.master file

The following is a sample line from **/etc/auto.master** file (displayed with **cat /etc/auto.master**):

```
/home /etc/auto.misc
```

The general format of maps is similar to the master map, however the "options" appear between the mount point and the location instead of at the end of the entry as in the master map:

```
mount-point   [options]   location
```

The variables used in this format are:

mount-point

This refers to the **autofs** mount point. This can be a single directory name for an indirect mount or the full path of the mount point for direct mounts. Each direct and indirect map entry key (***mount-point*** above) may be followed by a space separated list of offset directories (sub directory names each beginning with a "/") making them what is known as a multi-mount entry.

options

Whenever supplied, these are the mount options for the map entries that do not specify their own options.

location

This refers to the file system location such as a local file system path (preceded with the Sun map format escape character ":" for map names beginning with "/"), an NFS file system or other valid file system location.

The following is a sample of contents from a map file (for example, **/etc/auto.misc**):

```
payroll -fstype=nfs personnel:/dev/hda3
sales -fstype=ext3 :/dev/hda4
```

The first column in a map file indicates the **autofs** mount point (**sales** and **payroll** from the server called **personnel**). The second column indicates the options for the **autofs** mount while the third column indicates the source of the mount. Following the above configuration, the autofs mount points will be **/home/payroll** and **/home/sales**. The **-fstype=** option is often omitted and is generally not needed for correct operation.

The automounter will create the directories if they do not exist. If the directories exist before the automounter was started, the automounter will not remove them when it exits. You can start or restart the automount daemon by issuing either of the following two commands:

- **service autofs start** (if the automount daemon has stopped)
- **service autofs restart**

Using the above configuration, if a process requires access to an **autofs** unmounted directory such as **/home/payroll/2006/July.sxc**, the automount daemon automatically mounts the directory. If a timeout is specified, the directory will automatically be unmounted if the directory is not accessed for the timeout period.

You can view the status of the automount daemon by issuing the following command:

```
#  service autofs status
```

8.4.3. Overriding or Augmenting Site Configuration Files

It can be useful to override site defaults for a specific mount point on a client system. For example, consider the following conditions:

- Automounter maps are stored in NIS and the **/etc/nsswitch.conf** file has the following directive:

  ```
  automount:    files nis
  ```

- The **auto.master** file contains the following

  ```
  +auto.master
  ```

- The NIS **auto.master** map file contains the following:

  ```
  /home auto.home
  ```

- The NIS **auto.home** map contains the following:

  ```
  beth        fileserver.example.com:/export/home/beth
  joe        fileserver.example.com:/export/home/joe
  *       fileserver.example.com:/export/home/&
  ```

- The file map **/etc/auto.home** does not exist.

Given these conditions, let's assume that the client system needs to override the NIS map **auto.home** and mount home directories from a different server. In this case, the client will need to use the following **/etc/auto.master** map:

```
/home /etc/auto.home
+auto.master
```

The **/etc/auto.home** map contains the entry:

```
*    labserver.example.com:/export/home/&
```

Because the automounter only processes the first occurrence of a mount point, **/home** will contain the contents of **/etc/auto.home** instead of the NIS **auto.home** map.

Alternatively, to augment the site-wide **auto.home** map with just a few entries, create an **/etc/auto.home** file map, and in it put the new entries. At the end, include the NIS **auto.home** map. Then the **/etc/auto.home** file map will look similar to:

```
mydir someserver:/export/mydir
+auto.home
```

Given the NIS **auto.home** map listed above, **ls /home** would now output:

```
beth joe mydir
```

This last example works as expected because **autofs** does not include the contents of a file map of the same name as the one it is reading. As such, **autofs** moves on to the next map source in the **nsswitch** configuration.

8.4.4. Using LDAP to Store Automounter Maps

LDAP client libraries must be installed on all systems configured to retrieve automounter maps from LDAP. On Red Hat Enterprise Linux, the **openldap** package should be installed automatically as a dependency of the **automounter**. To configure LDAP access, modify **/etc/openldap/ldap.conf**. Ensure that BASE, URI, and schema are set appropriately for your site.

The most recently established schema for storing automount maps in LDAP is described by **rfc2307bis**. To use this schema it is necessary to set it in the **autofs** configuration (**/etc/sysconfig/autofs**) by removing the comment characters from the schema definition. For example:

Example 8.4. Setting autofs configuration

```
DEFAULT_MAP_OBJECT_CLASS="automountMap"
DEFAULT_ENTRY_OBJECT_CLASS="automount"
DEFAULT_MAP_ATTRIBUTE="automountMapName"
DEFAULT_ENTRY_ATTRIBUTE="automountKey"
DEFAULT_VALUE_ATTRIBUTE="automountInformation"
```

Ensure that these are the only schema entries not commented in the configuration. The **automountKey** replaces the **cn** attribute in the **rfc2307bis** schema. An **LDIF** of a sample configuration is described below:

Example 8.5. LDF configuration

```
# extended LDIF
#
# LDAPv3
# base <> with scope subtree
# filter: (&(objectclass=automountMap)(automountMapName=auto.master))
# requesting: ALL
#

# auto.master, example.com
dn: automountMapName=auto.master,dc=example,dc=com
objectClass: top
objectClass: automountMap
automountMapName: auto.master

# extended LDIF
#
# LDAPv3
# base <automountMapName=auto.master,dc=example,dc=com> with scope
subtree
# filter: (objectclass=automount)
# requesting: ALL
#

# /home, auto.master, example.com
dn: automountMapName=auto.master,dc=example,dc=com
objectClass: automount
cn: /home

automountKey: /home
automountInformation: auto.home

# extended LDIF
#
# LDAPv3
# base <> with scope subtree
# filter: (&(objectclass=automountMap)(automountMapName=auto.home))
# requesting: ALL
#

# auto.home, example.com
dn: automountMapName=auto.home,dc=example,dc=com
objectClass: automountMap
automountMapName: auto.home

# extended LDIF
#
# LDAPv3
# base <automountMapName=auto.home,dc=example,dc=com> with scope
subtree
```

```
# filter: (objectclass=automount)
# requesting: ALL
#

# foo, auto.home, example.com
dn: automountKey=foo,automountMapName=auto.home,dc=example,dc=com
objectClass: automount
automountKey: foo
automountInformation: filer.example.com:/export/foo

# /, auto.home, example.com
dn: automountKey=/,automountMapName=auto.home,dc=example,dc=com
objectClass: automount
automountKey: /
automountInformation: filer.example.com:/export/&
```

8.5. Common NFS Mount Options

Beyond mounting a file system with NFS on a remote host, it is also possible to specify other options at mount time to make the mounted share easier to use. These options can be used with manual **mount** commands, **/etc/fstab** settings, and **autofs**.

The following are options commonly used for NFS mounts:

intr

Allows NFS requests to be interrupted if the server goes down or cannot be reached.

lookupcache=*mode*

Specifies how the kernel should manage its cache of directory entries for a given mount point. Valid arguments for *mode* are **all**, **none**, or **pos**/**positive**.

nfsvers=*version*

Specifies which version of the NFS protocol to use, where *version* is 2, 3, or 4. This is useful for hosts that run multiple NFS servers. If no version is specified, NFS uses the highest version supported by the kernel and **mount** command.

The option **vers** is identical to **nfsvers**, and is included in this release for compatibility reasons.

noacl

Turns off all ACL processing. This may be needed when interfacing with older versions of Red Hat Enterprise Linux, Red Hat Linux, or Solaris, since the most recent ACL technology is not compatible with older systems.

nolock

Disables file locking. This setting is occasionally required when connecting to older NFS servers.

noexec

Prevents execution of binaries on mounted file systems. This is useful if the system is mounting a non-Linux file system containing incompatible binaries.

nosuid

Disables **set-user-identifier** or **set-group-identifier** bits. This prevents remote users from gaining higher privileges by running a **setuid** program.

port=*num*

port=num — Specifies the numeric value of the NFS server port. If ***num*** is **0** (the default), then **mount** queries the remote host's **rpcbind** service for the port number to use. If the remote host's NFS daemon is not registered with its **rpcbind** service, the standard NFS port number of TCP 2049 is used instead.

rsize=*num* and wsize=*num*

These settings speed up NFS communication for reads (**rsize**) and writes (**wsize**) by setting a larger data block size (*num*, in bytes), to be transferred at one time. Be careful when changing these values; some older Linux kernels and network cards do not work well with larger block sizes. For NFSv3, the default values for both parameters is set to 8192. For NFSv4, the default values for both parameters is set to 32768.

sec=*mode*

Its default setting is **sec=sys**, which uses local UNIX UIDs and GIDs. These use **AUTH_SYS** to authenticate NFS operations."

sec=krb5 uses Kerberos V5 instead of local UNIX UIDs and GIDs to authenticate users.

sec=krb5i uses Kerberos V5 for user authentication and performs integrity checking of NFS operations using secure checksums to prevent data tampering.

sec=krb5p uses Kerberos V5 for user authentication, integrity checking, and encrypts NFS traffic to prevent traffic sniffing. This is the most secure setting, but it also involves the most performance overhead.

tcp

Instructs the NFS mount to use the TCP protocol.

udp

Instructs the NFS mount to use the UDP protocol.

For a complete list of options and more detailed information on each one, refer to **man mount** and **man nfs**.

8.6. Starting and Stopping NFS

To run an NFS server, the **rpcbind**[1] service must be running. To verify that **rpcbind** is active, use the following command:

```
# systemctl status rpcbind
```

If the **rpcbind** service is running, then the **nfs** service can be started. To start an NFS server, use the following command:

```
# systemctl start nfs
```

To enable NFS to start at boot, use the following command:

```
# systemctl enable nfs-server
```

Note

For NFSv3, if NFS is set to start at boot time, the **nfs-lock** service needs to be enabled. On Red Hat Enterprise Linux 7.1 and later, **nfs-lock** starts automatically if needed, and an attempt to enable it manually fails. On Red Hat Enterprise Linux 7.0, check the status by running **systemctl status nfs-lock**. If **nfs-lock** is not enabled, run **systemctl start nfs-lock**. To set **nfs-lock** to automatically start on boot on Red Hat Enterprise Linux 7.0, run **systemctl enable nfs-lock**.

To stop the server, use:

```
    # systemctl stop nfs
```

The **restart** option is a shorthand way of stopping and then starting NFS. This is the most efficient way to make configuration changes take effect after editing the configuration file for NFS. To restart the server type:

```
    # systemctl restart nfs
```

After you edit the **/etc/sysconfig/nfs** file, restart the nfs-config service by running the following command for the new values to take effect:

```
    # systemctl restart nfs-config
```

The **try-restart** command only starts **nfs** if it is currently running. This command is the equivalent of **condrestart** (*conditional restart*) in Red Hat init scripts and is useful because it does not start the daemon if NFS is not running.

To conditionally restart the server type:

```
    # systemctl try-restart nfs
```

To reload the NFS server configuration file without restarting the service type:

```
    # systemctl reload nfs
```

8.7. NFS Server Configuration

There are two ways to configure exports on an NFS server:

- Manually editing the NFS configuration file, that is, **/etc/exports**, and
- through the command line, that is, by using the command **exportfs**

8.7.1. The /etc/exports Configuration File

The **/etc/exports** file controls which file systems are exported to remote hosts and specifies options. It follows the following syntax rules:

- Blank lines are ignored.
- To add a comment, start a line with the hash mark (#).
- You can wrap long lines with a backslash (\).
- Each exported file system should be on its own individual line.
- Any lists of authorized hosts placed after an exported file system must be separated by space characters.
- Options for each of the hosts must be placed in parentheses directly after the host identifier, without any spaces separating the host and the first parenthesis.

Each entry for an exported file system has the following structure:

```
export host(options)
```

The aforementioned structure uses the following variables:

export

The directory being exported

host

The host or network to which the export is being shared

options

The options to be used for *host*

It is possible to specify multiple hosts, along with specific options for each host. To do so, list them on the same line as a space-delimited list, with each hostname followed by its respective options (in parentheses), as in:

```
export host1(options1) host2(options2) host3(options3)
```

For information on different methods for specifying hostnames, refer to Section 8.7.4, “Hostname Formats”.

In its simplest form, the **/etc/exports** file only specifies the exported directory and the hosts permitted to access it, as in the following example:

Example 8.6. The /etc/exports file

```
/exported/directory bob.example.com
```

Here, **bob.example.com** can mount **/exported/directory/** from the NFS server. Because no options are specified in this example, NFS will use *default* settings.

The default settings are:

ro

The exported file system is read-only. Remote hosts cannot change the data shared on the file system. To allow hosts to make changes to the file system (that is, read/write), specify the **rw** option.

sync

The NFS server will not reply to requests before changes made by previous requests are written to disk. To enable asynchronous writes instead, specify the option **async**.

wdelay

The NFS server will delay writing to the disk if it suspects another write request is imminent. This can improve performance as it reduces the number of times the disk must be accesses by separate write commands, thereby reducing write overhead. To disable this, specify the **no_wdelay**. **no_wdelay** is only available if the default **sync** option is also specified.

root_squash

This prevents root users connected *remotely* (as opposed to locally) from having root privileges; instead, the NFS server will assign them the user ID **nfsnobody**. This effectively "squashes" the power of the remote root user to the lowest local user, preventing possible unauthorized writes on the remote server. To disable root squashing, specify **no_root_squash**.

To squash every remote user (including root), use **all_squash**. To specify the user and group IDs that the NFS server should assign to remote users from a particular host, use the **anonuid** and **anongid** options, respectively, as in:

```
export host(anonuid=uid,anongid=gid)
```

Here, *uid* and *gid* are user ID number and group ID number, respectively. The **anonuid** and **anongid** options allow you to create a special user and group account for remote NFS users to share.

By default, *access control lists* (*ACLs*) are supported by NFS under Red Hat Enterprise Linux. To disable this feature, specify the **no_acl** option when exporting the file system.

Each default for every exported file system must be explicitly overridden. For example, if the **rw** option is not specified, then the exported file system is shared as read-only. The following is a sample line from **/etc/exports** which overrides two default options:

```
/another/exported/directory 192.168.0.3(rw,async)
```

In this example **192.168.0.3** can mount **/another/exported/directory/** read/write and all writes to disk are asynchronous. For more information on exporting options, refer to **man exportfs**.

Other options are available where no default value is specified. These include the ability to disable sub-tree checking, allow access from insecure ports, and allow insecure file locks (necessary for certain early NFS client implementations). Refer to **man exports** for details on these less-used options.

Important

The format of the **/etc/exports** file is very precise, particularly in regards to use of the space character. Remember to always separate exported file systems from hosts and hosts from one another with a space character. However, there should be no other space characters in the file except on comment lines.

For example, the following two lines do not mean the same thing:

```
/home bob.example.com(rw)
/home bob.example.com (rw)
```

The first line allows only users from **bob.example.com** read/write access to the **/home** directory. The second line allows users from **bob.example.com** to mount the directory as read-only (the default), while the rest of the world can mount it read/write.

8.7.2. The exportfs Command

Every file system being exported to remote users with NFS, as well as the access level for those file systems, are listed in the **/etc/exports** file. When the **nfs** service starts, the **/usr/sbin/exportfs** command launches and reads this file, passes control to **rpc.mountd** (if NFSv2 or NFSv3) for the actual mounting process, then to **rpc.nfsd** where the file systems are then available to remote users.

When issued manually, the **/usr/sbin/exportfs** command allows the root user to selectively export or unexport directories without restarting the NFS service. When given the proper options, the **/usr/sbin/exportfs** command writes the exported file systems to **/var/lib/nfs/xtab**. Since **rpc.mountd** refers to the **xtab** file when deciding access privileges to a file system, changes to the list of exported file systems take effect immediately.

The following is a list of commonly-used options available for **/usr/sbin/exportfs**:

-r

Causes all directories listed in **/etc/exports** to be exported by constructing a new export list in **/etc/lib/nfs/xtab**. This option effectively refreshes the export list with any changes made to **/etc/exports**.

-a

Causes all directories to be exported or unexported, depending on what other options are passed to **/usr/sbin/exportfs**. If no other options are specified, **/usr/sbin/exportfs** exports all file systems specified in **/etc/exports**.

-o *file-systems*

Specifies directories to be exported that are not listed in **/etc/exports**. Replace *file-systems* with additional file systems to be exported. These file systems must be formatted in the same way they are specified in **/etc/exports**. This option is often used to test an exported file system before adding it permanently to the list of file systems to be exported. Refer to Section 8.7.1, “The **/etc/exports** Configuration File” for more information on **/etc/exports** syntax.

-i

Ignores **/etc/exports**; only options given from the command line are used to define exported file systems.

-u

Unexports all shared directories. The command **/usr/sbin/exportfs -ua** suspends NFS file sharing while keeping all NFS daemons up. To re-enable NFS sharing, use **exportfs -r**.

-v

Verbose operation, where the file systems being exported or unexported are displayed in greater detail when the **exportfs** command is executed.

If no options are passed to the **exportfs** command, it displays a list of currently exported file systems. For more information about the **exportfs** command, refer to **man exportfs**.

8.7.2.1. Using exportfs with NFSv4

In Red Hat Enterprise Linux 7, no extra steps are required to configure NFSv4 exports as any filesystems mentioned are automatically available to NFSv3 and NFSv4 clients using the same path. This was not the case in previous versions.

To prevent clients from using NFSv4, turn it off by setting **RPCNFSDARGS= -N 4** in **/etc/sysconfig/nfs**.

8.7.3. Running NFS Behind a Firewall

NFS requires **rpcbind**, which dynamically assigns ports for RPC services and can cause problems for configuring firewall rules. To allow clients to access NFS shares behind a firewall, edit the **/etc/sysconfig/nfs** file to set which ports the RPC services run on.

The **/etc/sysconfig/nfs** file does not exist by default on all systems. If **/etc/sysconfig/nfs** does not exist, create it and add the following variables. Replace *port* with an unused port number. If **/etc/sysconfig/nfs** already exists, edit the entries as needed:

RPCMOUNTDOPTS="-p *port*"

This adds "-p *port*" to the rpc.mount command line: **rpc.mount -p *port***.

LOCKD_TCPPORT=*port*

This sets the TCP port for nlockmgr.

LOCKD_UDPPORT=*port*

This sets the UDP port for nlockmgr.

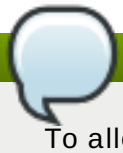
If NFS fails to start, check **/var/log/messages**. Commonly, NFS fails to start if you specify a port number that is already in use. After editing **/etc/sysconfig/nfs**, you need to restart the **nfs-config** service for the new values to take effect in Red Hat Enterprise Linux 7.2 and prior by running:

```
# systemctl restart nfs-config
```

Then, restart the NFS server:

```
# systemctl restart nfs-server
```

Run **rpcinfo -p** to confirm the changes have taken effect.



Note

To allow NFSv4.0 callbacks to pass through firewalls set **/proc/sys/fs/nfs/nfs_callback_tcpport** and allow the server to connect to that port on the client.

This process is not needed for NFSv4.1 or higher, and the other ports for **mountd**, **statd**, and **lockd** are not required in a pure NFSv4 environment.

8.7.3.1. Discovering NFS exports

There are two ways to discover which file systems an NFS server exports.

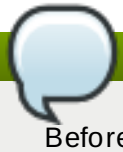
First, on any server that supports NFSv2 or NFSv3, use the **showmount** command:

```
$ showmount -e myserver
Export list for mysever
/exports/foo
/exports/bar
```

Second, on any server that supports NFSv4, mount **/** and look around.

```
# mount myserver:/ /mnt/
#cd /mnt/
exports
# ls exports
foo
bar
```

On servers that support both NFSv4 and either NFSv2 or NFSv3, both methods will work and give the same results.



Note

Before Red Hat Enterprise Linux 6 on older NFS servers, depending on how they are configured, it is possible to export filesystems to NFSv4 clients at different paths. Because these servers do not enable NFSv4 by default this should not normally be a problem.

8.7.4. Hostname Formats

The host(s) can be in the following forms:

Single machine

A fully-qualified domain name (that can be resolved by the server), hostname (that can be resolved by the server), or an IP address.

Series of machines specified with wildcards

Use the ***** or **?** character to specify a string match. Wildcards are not to be used with IP addresses; however, they may accidentally work if reverse DNS lookups fail. When specifying wildcards in fully qualified domain names, dots (**.**) are not included in the wildcard. For example, ***.example.com** includes **one.example.com** but does not **include one.two.example.com**.

IP networks

Use *a.b.c.d/z*, where *a.b.c.d* is the network and *z* is the number of bits in the netmask (for example 192.168.0.0/24). Another acceptable format is *a.b.c.d/netmask*, where *a.b.c.d* is the network and *netmask* is the netmask (for example, 192.168.100.8/255.255.255.0).

Netgroups

Use the format *@group-name*, where *group-name* is the NIS netgroup name.

8.7.5. NFS over RDMA

With Red Hat Enterprise Linux 7 the RDMA service is automatic so long as there is RDMA capable hardware present in the machine. As such the following procedure only needs to be followed if the RDMA package was not installed during machine installation.

Procedure 8.1. Enable RDMA from client

1. Install the RDMA package:

```
# yum install rdma
```

2. Remake the **initramfs**:

```
# dracut -f
```

3. Reboot.

8.8. Securing NFS

NFS is well-suited for sharing entire file systems with a large number of known hosts in a transparent manner. However, with ease-of-use comes a variety of potential security problems. Consider the following sections when exporting NFS file systems on a server or mounting them on a client. Doing so minimizes NFS security risks and better protects data on the server.

8.8.1. NFS Security with AUTH_SYS and export controls

Traditionally, NFS has given two options in order to control access to exported files.

First, the server restricts which hosts are allowed to mount which filesystems either by IP address or by host name.

Second, the server enforces file system permissions for users on NFS clients in the same way it does local users. Traditionally it does this using **AUTH_SYS** (also called **AUTH_UNIX**) which relies on the client to state the UID and GID's of the user. Be aware that this means a malicious or misconfigured client can easily get this wrong and allow a user access to files that it should not.

To limit the potential risks, administrators often allow read-only access or squash user permissions to a common user and group ID. Unfortunately, these solutions prevent the NFS share from being used in the way it was originally intended.

Additionally, if an attacker gains control of the DNS server used by the system exporting the NFS file system, the system associated with a particular hostname or fully qualified domain name can be pointed to an unauthorized machine. At this point, the unauthorized machine *is* the system permitted to mount the NFS share, since no username or password information is exchanged to provide additional security for the NFS mount.

Wildcards should be used sparingly when exporting directories through NFS, as it is possible for the scope of the wildcard to encompass more systems than intended.

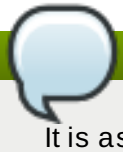
It is also possible to restrict access to the **rpcbind**[1] service with TCP wrappers. Creating rules with **iptables** can also limit access to ports used by **rpcbind**, **rpc.mountd**, and **rpc.nfsd**.

For more information on securing NFS and **rpcbind**, refer to **man iptables**.

8.8.2. NFS security with AUTH_GSS

The release of NFSv4 brought a revolution to NFS security by mandating the implementation of RPCSEC_GSS and the Kerberos version 5 GSS-API mechanism. However, RPCSEC_GSS and the Kerberos mechanism are also available for all versions of NFS. In FIPS mode, only FIPS-approved algorithms can be used.

With the RPCSEC_GSS Kerberos mechanism, the server no longer depends on the client to correctly represent which user is accessing the file, as is the case with AUTH_SYS. Instead, it uses cryptography to authenticate users to the server, preventing a malicious client from impersonating a user without having that user's kerberos credentials. This is also the easiest way to secure mounts as, after the Kerberos configuration has been done, it just works without any further alteration.



Note

It is assumed that a Kerberos ticket-granting server (KDC) is installed and configured correctly, prior to configuring an NFSv4 server. Kerberos is a network authentication system which allows clients and servers to authenticate to each other through use of symmetric encryption and a trusted third party, the KDC. For more information on Kerberos see Red Hat's *Identity Management Guide*.

To set up RPCSEC_GSS, use the following procedure:

Procedure 8.2. Set up RPCSEC_GSS

1. Create **nfs/client.*mydomain*@*MYREALM*** and **nfs/server.*mydomain*@*MYREALM*** principals.
2. Add the corresponding keys to keytabs for the client and server.
3. On the server side, add **sec=krb5:krb5i:krb5p** to the export. To continue allowing AUTH_SYS, add **sec=sys:krb5:krb5i:krb5p** instead.
4. On the client side, add **sec=krb5** (or **sec=krb5i**, or **sec=krb5p** depending on the setup) to the mount options.

For more information, such as the difference between **krb5**, **krb5i**, and **krb5p**, refer to the **exports** and **nfs** man pages or to Section 8.5, "Common NFS Mount Options".

For more information on the **RPCSEC_GSS** framework, including how **rpc.svcgssd** and **rpc.gssd** inter-operate, refer to http://www.citi.umich.edu/projects/nfsv4/gssd/.

8.8.2.1. NFS security with NFSv4

NFSv4 includes ACL support based on the Microsoft Windows NT model, not the POSIX model, because of the former's features and wide deployment.

Another important security feature of NFSv4 is the removal of the use of the **MOUNT** protocol for mounting file systems. This protocol presented possible security holes because of the way that it processed file handles.

8.8.3. File Permissions

Once the NFS file system is mounted read/write by a remote host, the only protection each shared file has is its permissions. If two users that share the same user ID value mount the same NFS file system, they can modify each others' files. Additionally, anyone logged in as root on the client system can use the **su -** command to access any files with the NFS share.

By default, access control lists (ACLs) are supported by NFS under Red Hat Enterprise Linux. Red Hat recommends that this feature is kept enabled.

By default, NFS uses *root squashing* when exporting a file system. This sets the user ID of anyone accessing the NFS share as the root user on their local machine to **nobody**. Root squashing is controlled by the default option **root_squash**; for more information about this option, refer to Section 8.7.1, "The **/etc/exports** Configuration File". If possible, never disable root squashing.

When exporting an NFS share as read-only, consider using the **all_squash** option. This option makes every user accessing the exported file system take the user ID of the **nfsnobody** user.

8.9. NFS and rpcbind

Note

The following section only applies to NFSv3 implementations that require the **rpcbind** service for backward compatibility.

The **rpcbind**[1] utility maps RPC services to the ports on which they listen. RPC processes notify **rpcbind** when they start, registering the ports they are listening on and the RPC program numbers they expect to serve. The client system then contacts **rpcbind** on the server with a particular RPC program number. The **rpcbind** service redirects the client to the proper port number so it can communicate with the requested service.

Because RPC-based services rely on **rpcbind** to make all connections with incoming client requests, **rpcbind** must be available before any of these services start.

The **rpcbind** service uses TCP wrappers for access control, and access control rules for **rpcbind** affect *all* RPC-based services. Alternatively, it is possible to specify access control rules for each of the NFS RPC daemons. The **man** pages for **rpc.mountd** and **rpc.statd** contain information regarding the precise syntax for these rules.

8.9.1. Troubleshooting NFS and rpcbind

Because **rpcbind**[1] provides coordination between RPC services and the port numbers used to communicate with them, it is useful to view the status of current RPC services using **rpcbind** when troubleshooting. The **rpcinfo** command shows each RPC-based service with port numbers, an RPC program number, a version number, and an IP protocol type (TCP or UDP).

To make sure the proper NFS RPC-based services are enabled for **rpcbind**, issue the following command:

```
# rpcinfo -p
```

Example 8.7. rpcinfo -p command output

The following is sample output from this command:

```
program vers proto   port  service
    100021    1   udp  32774  nlockmgr
    100021    3   udp  32774  nlockmgr
    100021    4   udp  32774  nlockmgr
    100021    1   tcp  34437  nlockmgr
    100021    3   tcp  34437  nlockmgr
    100021    4   tcp  34437  nlockmgr
    100011    1   udp    819  rquotad
    100011    2   udp    819  rquotad
    100011    1   tcp    822  rquotad
    100011    2   tcp    822  rquotad
    100003    2   udp   2049  nfs
    100003    3   udp   2049  nfs
    100003    2   tcp   2049  nfs
    100003    3   tcp   2049  nfs
    100005    1   udp    836  mountd
    100005    1   tcp    839  mountd
    100005    2   udp    836  mountd
    100005    2   tcp    839  mountd
    100005    3   udp    836  mountd
    100005    3   tcp    839  mountd
```

If one of the NFS services does not start up correctly, **rpcbind** will be unable to map RPC requests from clients for that service to the correct port. In many cases, if NFS is not present in **rpcinfo** output, restarting NFS causes the service to correctly register with **rpcbind** and begin working.

For more information and a list of options on **rpcinfo**, refer to its **man** page.

8.10. References

Administering an NFS server can be a challenge. Many options, including quite a few not mentioned in this chapter, are available for exporting or mounting NFS shares. Consult the following sources for more information.

Installed Documentation

- **man mount** — Contains a comprehensive look at mount options for both NFS server and client configurations.
- **man fstab** — Gives details for the format of the **/etc/fstab** file used to mount file systems at boot-time.
- **man nfs** — Provides details on NFS-specific file system export and mount options.
- **man exports** — Shows common options used in the **/etc/exports** file when exporting NFS file systems.

Useful Websites

- http://linux-nfs.org — The current site for developers where project status updates can be viewed.
- http://nfs.sourceforge.net/ — The old home for developers which still contains a lot of useful information.
- http://www.citi.umich.edu/projects/nfsv4/linux/ — An NFSv4 for Linux 2.6 kernel resource.
- http://www.vanemery.com/Linux/NFSv4/NFSv4-no-rpcsec.html — Describes the details of NFSv4 with Fedora Core 2, which includes the 2.6 kernel.
- http://citeseer.ist.psu.edu/viewdoc/summary?doi=10.1.1.111.4086 — An excellent whitepaper on the features and enhancements of the NFS Version 4 protocol.

Related Books

- *Managing NFS and NIS* by Hal Stern, Mike Eisler, and Ricardo Labiaga; O'Reilly & Associates — Makes an excellent reference guide for the many different NFS export and mount options available.
- *NFS Illustrated* by Brent Callaghan; Addison-Wesley Publishing Company — Provides comparisons of NFS to other network file systems and shows, in detail, how NFS communication occurs.

---

[1] The **rpcbind** service replaces **portmap**, which was used in previous versions of Red Hat Enterprise Linux to map RPC program numbers to IP address port number combinations. For more information, refer to Section 8.1.1, “Required Services”.

Chapter 9. FS-Cache

FS-Cache is a persistent local cache that can be used by file systems to take data retrieved from over the network and cache it on local disk. This helps minimize network traffic for users accessing data from a file system mounted over the network (for example, NFS).

The following diagram is a high-level illustration of how FS-Cache works:

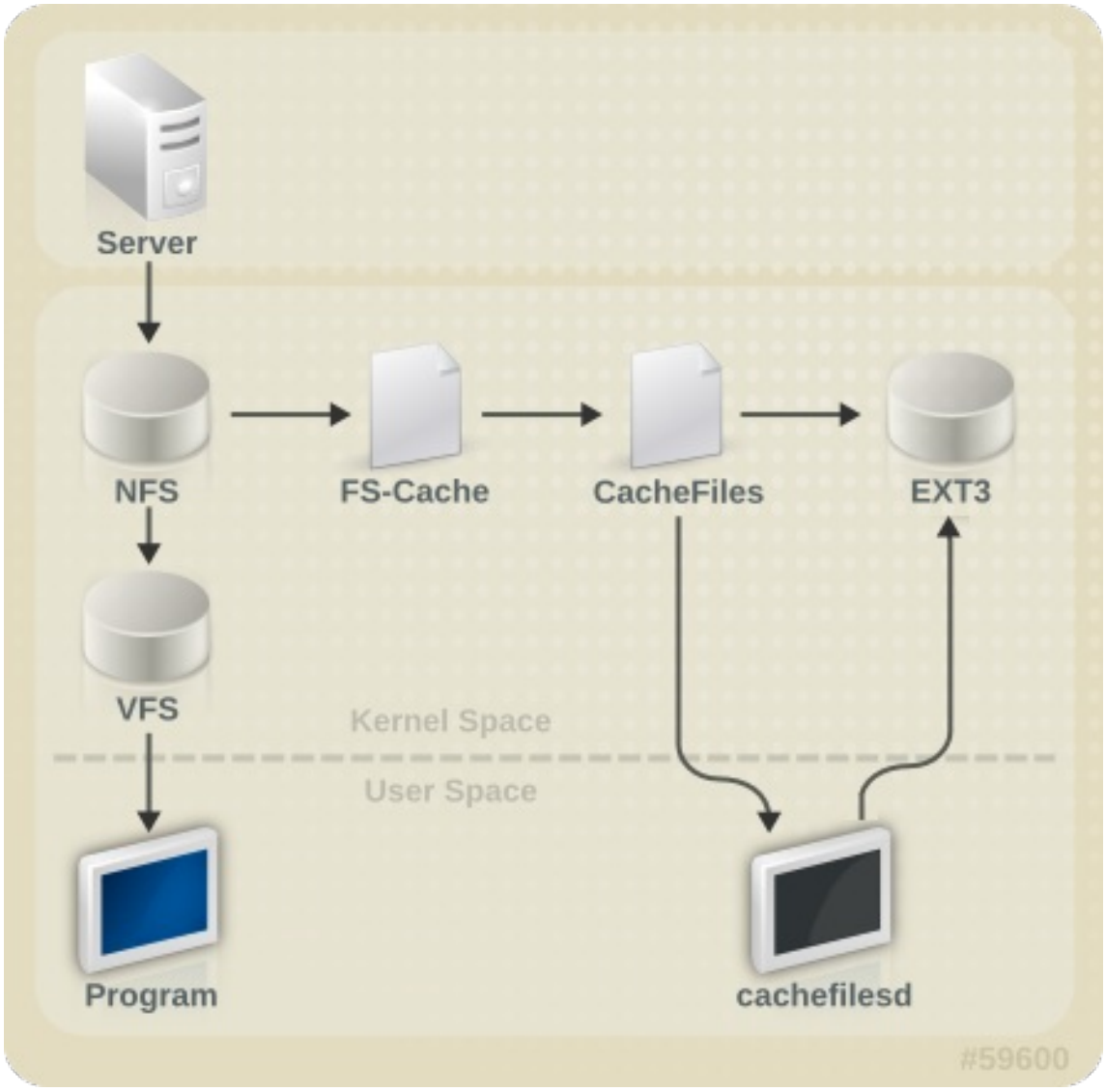


Figure 9.1. FS-Cache Overview

FS-Cache is designed to be as transparent as possible to the users and administrators of a system. Unlike **cachefs** on Solaris, FS-Cache allows a file system on a server to interact directly with a client's local cache without creating an overmounted file system. With NFS, a mount option instructs the client to mount the NFS share with FS-cache enabled.

FS-Cache does not alter the basic operation of a file system that works over the network - it merely provides that file system with a persistent place in which it can cache data. For instance, a client can still mount an NFS share whether or not FS-Cache is enabled. In addition, cached NFS can handle files that won't fit into the cache (whether individually or collectively) as files can be partially cached and do not have to be read completely up front. FS-Cache also hides all I/O errors that occur in the cache from the client file system driver.

To provide caching services, FS-Cache needs a *cache back-end*. A cache back-end is a storage driver configured to provide caching services (i.e. **cachefiles**). In this case, FS-Cache requires a mounted block-based file system that supports **bmap** and extended attributes (e.g. ext3) as its cache back-end.

FS-Cache cannot arbitrarily cache any file system, whether through the network or otherwise: the shared file system's driver must be altered to allow interaction with FS-Cache, data storage/retrieval, and metadata setup and validation. FS-Cache needs *indexing keys* and *coherency data* from the cached file system to support persistence: indexing keys to match file system objects to cache objects, and coherency data to determine whether the cache objects are still valid.

Note

In Red Hat Enterprise Linux 7, **cachefilesd** is not installed by default and will need to be installed manually.

9.1. Performance Guarantee

FS-Cache does *not* guarantee increased performance, however it ensures consistent performance by avoiding network congestion. Using a cache back-end incurs a performance penalty: for example, cached NFS shares add disk accesses to cross-network lookups. While FS-Cache tries to be as asynchronous as possible, there are synchronous paths (e.g. reads) where this isn't possible.

For example, using FS-Cache to cache an NFS share between two computers over an otherwise unladen GigE network will not demonstrate any performance improvements on file access. Rather, NFS requests would be satisfied faster from server memory rather than from local disk.

The use of FS-Cache, therefore, is a *compromise* between various factors. If FS-Cache is being used to cache NFS traffic, for instance, it may slow the client down a little, but massively reduce the network and server loading by satisfying read requests locally without consuming network bandwidth.

9.2. Setting Up a Cache

Currently, Red Hat Enterprise Linux 7 only provides the **cachefiles** caching back-end. The **cachefilesd** daemon initiates and manages **cachefiles**. The **/etc/cachefilesd.conf** file controls how **cachefiles** provides caching services. To configure a cache back-end of this type, the **cachefilesd** package must be installed.

The first setting to configure in a cache back-end is which directory to use as a cache. To configure this, use the following parameter:

```
$ dir /path/to/cache
```

Typically, the cache back-end directory is set in **/etc/cachefilesd.conf** as **/var/cache/fscache**, as in:

```
$ dir /var/cache/fscache
```

FS-Cache will store the cache in the file system that hosts */path/to/cache*. On a laptop, it is advisable to use the root file system (**/**) as the host file system, but for a desktop machine it would be more prudent to mount a disk partition specifically for the cache.

File systems that support functionalities required by FS-Cache cache back-end include the Red Hat Enterprise Linux 7 implementations of the following file systems:

- ext3 (with extended attributes enabled)
- ext4
- BTRFS
- XFS

The host file system must support user-defined extended attributes; FS-Cache uses these attributes to store coherency maintenance information. To enable user-defined extended attributes for ext3 file systems (i.e. ***device***), use:

```
# tune2fs -o user_xattr /dev/device
```

Alternatively, extended attributes for a file system can be enabled at mount time, as in:

```
# mount /dev/device /path/to/cache -o user_xattr
```

The cache back-end works by maintaining a certain amount of free space on the partition hosting the cache. It grows and shrinks the cache in response to other elements of the system using up free space, making it safe to use on the root file system (for example, on a laptop). FS-Cache sets defaults on this behavior, which can be configured via *cache cull limits*. For more information about configuring cache cull limits, refer to Section 9.4, “Setting Cache Cull Limits”.

Once the configuration file is in place, start up the **cachefilesd** daemon:

```
# service cachefilesd start
```

To configure **cachefilesd** to start at boot time, execute the following command as root:

```
# chkconfig cachefilesd on
```

9.3. Using the Cache With NFS

NFS will not use the cache unless explicitly instructed. To configure an NFS mount to use FS-Cache, include the **-o fsc** option to the **mount** command:

```
# mount nfs-share:/ /mount/point -o fsc
```

All access to files under ***/mount/point*** will go through the cache, unless the file is opened for direct I/O or writing (refer to Section 9.3.2, “Cache Limitations With NFS” for more information). NFS indexes cache contents using NFS file handle, *not* the file name; this means that hard-linked files share the cache correctly.

Caching is supported in version 2, 3, and 4 of NFS. However, each version uses different branches for caching.

9.3.1. Cache Sharing

There are several potential issues to do with NFS cache sharing. Because the cache is persistent, blocks of data in the cache are indexed on a sequence of four keys:

- Level 1: Server details
- Level 2: Some mount options; security type; FSID; uniquifier
- Level 3: File Handle
- Level 4: Page number in file

To avoid coherency management problems between superblocks, all NFS superblocks that wish to cache data have unique Level 2 keys. Normally, two NFS mounts with same source volume and options will share a superblock, and thus share the caching, even if they mount different directories within that volume.

Example 9.1. Cache sharing

Take the following two **mount** commands:

```
mount home0:/disk0/fred /home/fred -o fsc

mount home0:/disk0/jim /home/jim -o fsc
```

Here, **/home/fred** and **/home/jim** will likely share the superblock as they have the same options, especially if they come from the same volume/partition on the NFS server (**home0**). Now, consider the next two subsequent mount commands:

```
mount home0:/disk0/fred /home/fred -o fsc,rsize=230

mount home0:/disk0/jim /home/jim -o fsc,rsize=231
```

In this case, **/home/fred** and **/home/jim** will not share the superblock as they have different network access parameters, which are part of the Level 2 key. The same goes for the following mount sequence:

```
mount home0:/disk0/fred /home/fred1 -o fsc,rsize=230

mount home0:/disk0/fred /home/fred2 -o fsc,rsize=231
```

Here, the contents of the two subtrees (**/home/fred1** and **/home/fred2**) will be cached *twice*.

Another way to avoid superblock sharing is to suppress it explicitly with the **nosharecache** parameter. Using the same example:

```
mount home0:/disk0/fred /home/fred -o nosharecache,fsc

mount home0:/disk0/jim /home/jim -o nosharecache,fsc
```

However, in this case only one of the superblocks will be permitted to use cache since there is nothing to distinguish the Level 2 keys of **home0:/disk0/fred** and **home0:/disk0/jim**. To address this, add a *unique identifier* on at least one of the mounts, i.e. **fsc=*unique-identifier***. For example:

```
mount home0:/disk0/fred /home/fred -o nosharecache,fsc

mount home0:/disk0/jim /home/jim -o nosharecache,fsc=jim
```

Here, the unique identifier **jim** will be added to the Level 2 key used in the cache for **/home/jim**.

9.3.2. Cache Limitations With NFS

Opening a file from a shared file system for direct I/O will automatically bypass the cache. This is because this type of access must be direct to the server.

Opening a file from a shared file system for writing will not work on NFS version 2 and 3. The protocols of these versions do not provide sufficient coherency management information for the client to detect a concurrent write to the same file from another client.

As such, opening a file from a shared file system for either direct I/O or writing will flush the cached copy of the file. FS-Cache will not cache the file again until it is no longer opened for direct I/O or writing.

Furthermore, this release of FS-Cache only caches regular NFS files. FS-Cache will *not* cache directories, symlinks, device files, FIFOs and sockets.

9.4. Setting Cache Cull Limits

The **cachefilesd** daemon works by caching remote data from shared file systems to free space on the disk. This could potentially consume all available free space, which could be bad if the disk also housed the root partition. To control this, **cachefilesd** tries to maintain a certain amount of free space by discarding old objects (i.e. accessed less recently) from the cache. This behavior is known as *cache culling*.

Cache culling is done on the basis of the percentage of blocks and the percentage of files available in the underlying file system. There are six limits controlled by settings in **/etc/cachefilesd.conf**:

brun *N*% (percentage of blocks) , frun *N*% (percentage of files)

If the amount of free space and the number of available files in the cache rises above both these limits, then culling is turned off.

bcull *N*% (percentage of blocks), fcull *N*% (percentage of files)

If the amount of available space or the number of files in the cache falls below either of these limits, then culling is started.

bstop *N*% (percentage of blocks), fstop *N*% (percentage of files)

If the amount of available space or the number of available files in the cache falls below either of these limits, then no further allocation of disk space or files is permitted until culling has raised things above these limits again.

The default value of **N** for each setting is as follows:

- **brun**/**frun** - 10%
- **bcull**/**fcull** - 7%
- **bstop**/**fstop** - 3%

When configuring these settings, the following must hold true:

0 <= **bstop** < **bcull** < **brun** < 100

0 <= **fstop** < **fcull** < **frun** < 100

These are the percentages of available space and available files and do not appear as 100 minus the percentage displayed by the **df** program.

Important

Culling depends on both b*xxx* and f*xxx* pairs simultaneously; they can not be treated separately.

9.5. Statistical Information

FS-Cache also keeps track of general statistical information. To view this information, use:

```
cat /proc/fs/fscache/stats
```

FS-Cache statistics includes information on decision points and object counters. For more details on the statistics provided by FS-Cache, refer to the following kernel document:

/usr/share/doc/kernel-doc-*version*/Documentation/filesystems/caching/fscache.txt

9.6. References

For more information on **cachefilesd** and how to configure it, refer to **man cachefilesd** and **man cachefilesd.conf**. The following kernel documents also provide additional information:

- **/usr/share/doc/cachefilesd-*version-number*/README**
- **/usr/share/man/man5/cachefilesd.conf.5.gz**
- **/usr/share/man/man8/cachefilesd.8.gz**

For general information about FS-Cache, including details on its design constraints, available statistics, and capabilities, refer to the following kernel document:

/usr/share/doc/kernel-doc-*version*/Documentation/filesystems/caching/fscache.txt

Part II. Storage Administration

The Storage Administration section starts with storage considerations for Red Hat Enterprise Linux 7. Instructions regarding partitions, logical volume management, and swap partitions follow this. Disk Quotas, RAID systems are next, followed by the functions of mount command, volume_key, and acls. SSD tuning, write barriers, I/O limits and diskless systems follow this. The large chapter of Online Storage is next, and finally device mapper multipathing and virtual storage to finish.

Use the following Table of Contents to explore these Storage Administration tasks.

Chapter 10. Storage Considerations During Installation

Many storage device and file system settings can only be configured at install time. Other settings, such as file system type, can only be modified up to a certain point without requiring a reformat. As such, it is prudent that you plan your storage configuration accordingly before installing Red Hat Enterprise Linux 7.

This chapter discusses several considerations when planning a storage configuration for your system. For actual installation instructions (including storage configuration during installation), refer to the *Installation Guide* provided by Red Hat.

For information on what Red Hat officially supports with regards to size and storage limits, refer to the article http://www.redhat.com/resourcelibrary/articles/articles-red-hat-enterprise-linux-6-technology-capabilities-and-limits.

10.1. Special Considerations

This section enumerates several issues and factors to consider for specific storage configurations.

Separate Partitions for /home, /opt, /usr/local

If it is likely that you will upgrade your system in the future, place **/home**, **/opt**, and **/usr/local** on a separate device. This will allow you to reformat the devices/file systems containing the operating system while preserving your user and application data.

DASD and zFCP Devices on IBM System Z

On the IBM System Z platform, DASD and zFCP devices are configured via the *Channel Command Word* (CCW) mechanism. CCW paths must be explicitly added to the system and then brought online. For DASD devices, this is simply means listing the device numbers (or device number ranges) as the **DASD=** parameter at the boot command line or in a CMS configuration file.

For zFCP devices, you must list the device number, *logical unit number* (LUN), and *world wide port name* (WWPN). Once the zFCP device is initialized, it is mapped to a CCW path. The **FCP_x=** lines on the boot command line (or in a CMS configuration file) allow you to specify this information for the installer.

Encrypting Block Devices Using LUKS

Formatting a block device for encryption using LUKS/**dm-crypt** will destroy any existing formatting on that device. As such, you should decide which devices to encrypt (if any) before the new system's storage configuration is activated as part of the installation process.

Stale BIOS RAID Metadata

Moving a disk from a system configured for firmware RAID *without* removing the RAID metadata from the disk can prevent **Anaconda** from correctly detecting the disk.

Warning

Removing/deleting RAID metadata from disk could potentially destroy any stored data. Red Hat recommends that you back up your data before proceeding.

To delete RAID metadata from the disk, use the following command:

```
dmraid -r -E /device/
```

For more information about managing RAID devices, refer to **man dmraid** and Chapter 17, *Redundant Array of Independent Disks (RAID)*.

iSCSI Detection and Configuration

For plug and play detection of iSCSI drives, configure them in the firmware of an iBFT boot-capable *network interface card* (NIC). CHAP authentication of iSCSI targets is supported during installation. However, iSNS discovery is not supported during installation.

FCoE Detection and Configuration

For plug and play detection of *Fibre Channel over Ethernet* (FCoE) drives, configure them in the firmware of an EDD boot-capable NIC.

DASD

Direct-access storage devices (DASD) cannot be added/configured during installation. Such devices are specified in the CMS configuration file.

Block Devices with DIF/DIX Enabled

DIF/DIX is a hardware checksum feature provided by certain SCSI host bus adapters and block devices. When DIF/DIX is enabled, errors will occur if the block device is used as a general-purpose block device. Buffered I/O or **mmap(2)**-based I/O will not work reliably, as there are no interlocks in the buffered write path to prevent buffered data from being overwritten after the DIF/DIX checksum has been calculated.

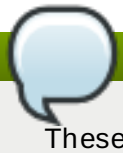
This will cause the I/O to later fail with a checksum error. This problem is common to all block device (or file system-based) buffered I/O or **mmap(2)** I/O, so it is not possible to work around these errors caused by overwrites.

As such, block devices with DIF/DIX enabled should only be used with applications that use **O_DIRECT**. Such applications should use the raw block device. Alternatively, it is also safe to use the XFS file system on a DIF/DIX enabled block device, as long as only **O_DIRECT** I/O is issued through the file system. XFS is the only file system that does not fall back to buffered I/O when doing certain allocation operations.

The responsibility for ensuring that the I/O data does not change after the DIF/DIX checksum has been computed always lies with the application, so only applications designed for use with **O_DIRECT** I/O and DIF/DIX hardware should use DIF/DIX.

Chapter 11. File System Check

Filesystems may be checked for consistency, and optionally repaired, with filesystem-specific userspace tools. These tools are often referred to as **fsck** tools, where **fsck** is a shortened version of *file system check*.



Note

These filesystem checkers only guarantee metadata consistency across the filesystem; they have no awareness of the actual data contained within the filesystem and are not data recovery tools.

Filesystem inconsistencies can occur for various reasons, including but not limited to hardware errors, storage administration errors, and software bugs.

Before modern metadata-journaling filesystems became common, a filesystem check was required any time a system crashed or lost power. This was because a filesystem update could have been interrupted, leading to an inconsistent state. As a result, a filesystem check is traditionally run on each filesystem listed in **/etc/fstab** at boot-time. For journaling filesystems, this is usually a very short operation, because the filesystem's metadata journaling ensures consistence even after a crash.

However, there are times when a filesystem inconsistency or corruption may occur, even for journaling filesystems. When this happens, the filesystem checker must be used to repair the filesystem. The following will provide best practices and other useful information when performing this procedure.

Important

Red Hat does not recommended this unless the machine does not boot, the file system is extremely large, or the file system is on remote storage. It is possible to disable file system check at boot by setting the sixth field in /etc/fstab to 0.

11.1. Best Practices for fsck

Generally, running the filesystem check and repair tool can be expected to automatically repair at least some of the inconsistencies it finds. In some cases, severely damaged inodes or directories may be discarded if they cannot be repaired. Significant changes to the filesystem may occur. To ensure that unexpected or undesirable changes are not permanently made, perform the following precautionary steps:

Dry run

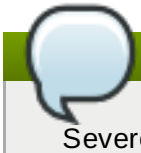
Most filesystem checkers have a mode of operation which checks but does not repair the filesystem. In this mode, the checker will print any errors that it finds and actions that it would have taken, without actually modifying the filesystem.

Note

Later phases of consistency checking may print extra errors as it discovers inconsistencies which would have been fixed in early phases if it were running in repair mode.

Operate first on a filesystem image

Most filesystems support the creation of a *metadata image*, a sparse copy of the filesystem which contains only metadata. Because filesystem checkers operate only on metadata, such an image can be used to perform a dry run of an actual filesystem repair, to evaluate what changes would actually be made. If the changes are acceptable, the repair can then be performed on the filesystem itself.



Note

Severely damaged filesystems may cause problems with metadata image creation.

Save a filesystem image for support investigations

A pre-repair filesystem metadata image can often be useful for support investigations if there is a possibility that the corruption was due to a software bug. Patterns of corruption present in the pre-repair image may aid in root-cause analysis.

Operate only on unmounted filesystems

A filesystem repair must be run only on unmounted filesystems. The tool must have sole access to the filesystem or further damage may result. Most filesystem tools enforce this requirement in repair mode, although some only support check-only mode on a mounted filesystem. If check-only mode is run on a mounted filesystem, it may find spurious errors that would not be found when run on an unmounted filesystem.

Disk errors

Filesystem check tools cannot repair hardware problems. A filesystem must be fully readable and writable if repair is to operate successfully. If a filesystem was corrupted due to a hardware error, the filesystem must first be moved to a good disk, for example with the **dd(8)** utility.

11.2. Filesystem-Specific Information for fsck

11.2.1. ext2, ext3, and ext4

All of these filesytems use the **e2fsck** binary to perform filesystem checks and repairs. The filenames **fsck.ext2**, **fsck.ext3**, and **fsck.ext4** are hardlinks to this same binary. These binaries are run automatically at boot time and their behavior differs based on the filesystem being checked and the state of the filesystem.

A full filesystem check and repair is invoked for ext2, which is not a metadata journaling filesystem, and for ext4 filesystems without a journal.

For ext3 and ext4 filesystems with metadata journaling, the journal is replayed in userspace and the binary exited. This is the default action as journal replay ensures a consistent filesystem after a

crash.

If these filesystems encounter metadata inconsistencies while mounted, they will record this fact in the filesystem super block. If **e2fsck** finds that a filesystem is marked with such an error **e2fsck** will perform a full check after replaying the journal (if present).

e2fsck may ask for user input during the run if the **-p** option is not specified. The **-p** option tells **e2fsck** to automatically do all repairs that may be done safely. If user intervention is required, **e2fsck** will indicate the unfixed problem in its output and reflect this status in the exit code.

Commonly used **e2fsck** run-time options include:

-n

No-modify mode. Check-only operation.

-b superblock

Specify block number of an alternate suprerblock if the primary one is damaged.

-f

Force full check even if the superblock has no recorded errors.

-j journal-dev

Specify the external journal device, if any.

-p

Automatically repair or "preen" the filesystem with no user input.

-y

Assume an answer of "yes" to all questions.

All options for **e2fsck** are specified in the **e2fsck(8)** manual page.

The following five basic phases are performed by **e2fsck** while running:

1. Inode, block, and size checks.
2. Directory structure checks.
3. Directory connectivity checks.
4. Reference count checks.
5. Group summary info checks.

The **e2image(8)** utility can be used to create a metadata image prior to repair for diagnostic or testing purposes. The **-r** option should be used for testing purposes in order to create a sparse file of the same size as the filesystem itself. **e2fsck** can then operate directly on the resulting file. The **-Q** option should be specified if the image is to be archived or provided for diagnostic. This creates a more compact file format suitable for transfer.

11.2.2. XFS

No repair is performed automatically at boot time. To initiate a filesystem check or repair, the **xfs_repair** tool is used.

Note

Although an **fsck.xfs** binary is present in the *xfsprogs* package, this is present only to satisfy initscripts that look for an **fsck.*filesystem*** binary at boot time. **fsck.xfs** immediately exits with an exit code of 0.

Another thing to be aware of is that older *xfsprogs* packages contain an **xfs_check** tool. This tool is very slow and does not scale well for large filesystems. As such, it has been depreciated in favor of **xfs_repair -n**.

A clean log on a filesystem is required for **xfs_repair** to operate. If the filesystem was not cleanly unmounted, it should be mounted and unmounted prior to using **xfs_repair**. If the log is corrupt and cannot be replayed, the **-L** option may be used to zero the log.

Important

The **-L** option must only be used if the log cannot be replayed. The option discards all metadata updates in the log and will result in further inconsistencies.

It is possible to run **xfs_repair** in a dry run, check-only mode by using the **-n** option. No changes will be made to the filesystem when this option is specified.

xfs_repair takes very few options. Commonly used options include:

-n

No modify mode. Check-only operation.

-L

Zero metadata log. Use only if log cannot be replayed with mount.

-m maxmem

Limit memory used during run to maxmem MB. 0 can be specified to obtain a rough estimate of the minimum memory required.

-l logdev

Specify the external log device, if present.

All options for **xfs_repair** are specified in the **xfs_repair(8)** manual page.

The following eight basic phases are performed by **xfs_repair** while running:

1. Inode and inode blockmap (addressing) checks.
2. Inode allocation map checks.
3. Inode size checks.
4. Directory checks.
5. Pathname checks.

6. Link count checks.
7. Freemap checks.
8. Super block checks.

These phases, as well as messages printed during operation, are documented in depth in the **xfs_repair(8)** manual page.

xfs_repair is not interactive. All operations are performed automatically with no input from the user.

If it is desired to create a metadata image prior to repair for diagnostic or testing purposes, the **xfs_metadump(8)** and **xfs_mdrestore(8)** utilities may be used.

11.2.3. Btrfs

The **btrfsck** tool is used to check and repair btrfs filesystems. This tool is still in early development and may not detect or repair all types of filesystem corruption.

By default, **btrfsck** does not make changes to the filesystem; that is, it runs check-only mode by default. If repairs are desired the **--repair** option must be specified.

The following three basic phases are performed by **btrfsck** while running:

1. Extent checks.
2. Filesystem root checks.
3. Root reference count checks.

The **btrfs-image(8)** utility can be used to create a metadata image prior to repair for diagnostic or testing purposes.

Chapter 12. Partitions

The utility **parted** allows users to:

- View the existing partition table
- Change the size of existing partitions
- Add partitions from free space or additional hard drives

By default, the **parted** package is included when installing Red Hat Enterprise Linux. To start **parted**, log in as root and type the command **parted** ***/dev/sda*** at a shell prompt (where ***/dev/sda*** is the device name for the drive you want to configure).

If you want to remove or resize a partition, the device on which that partition resides must not be in use. Creating a new partition on a device which is in use—while possible—is not recommended.

For a device to not be in use, none of the partitions on the device can be mounted, and any swap space on the device must not be enabled.

As well, the partition table should not be modified while it is in use because the kernel may not properly recognize the changes. If the partition table does not match the actual state of the mounted partitions, information could be written to the wrong partition, resulting in lost and overwritten data.

The easiest way to achieve this it to boot your system in rescue mode. When prompted to mount the file system, select **Skip**.

Alternately, if the drive does not contain any partitions in use (system processes that use or lock the file system from being unmounted), you can unmount them with the **umount** command and turn off all the swap space on the hard drive with the **swapoff** command.

Table 12.1, "**parted** commands" contains a list of commonly used **parted** commands. The sections that follow explain some of these commands and arguments in more detail.

Table 12.1. parted commands

Command	Description
check ***minor-num***	Perform a simple check of the file system
cp ***from to***	Copy file system from one partition to another; *from* and *to* are the minor numbers of the partitions
help	Display list of available commands
mklabel ***label***	Create a disk label for the partition table
mkfs ***minor-num file-system-type***	Create a file system of type *file-system-type*
mkpart ***part-type fs-type start-mb end-mb***	Make a partition without creating a new file system
mkpartfs ***part-type fs-type start-mb end-mb***	Make a partition and create the specified file system
move ***minor-num start-mb end-mb***	Move the partition
name ***minor-num name***	Name the partition for Mac and PC98 disklabels only
print	Display the partition table
quit	Quit **parted**
rescue *start-mb end-mb*	Rescue a lost partition from *start-mb* to *end-mb*
resize ***minor-num start-mb end-mb***	Resize the partition from *start-mb* to *end-mb*

Command	Description
rm *minor-num*	Remove the partition
select *device*	Select a different device to configure
set *minor-num flag state*	Set the flag on a partition; *state* is either on or off
toggle [*NUMBER* [*FLAG*]	Toggle the state of *FLAG* on partition *NUMBER*
unit *UNIT*	Set the default unit to *UNIT*

12.1. Viewing the Partition Table

After starting **parted**, use the command **print** to view the partition table. A table similar to the following appears:

Example 12.1. Partition table

```
Model: ATA ST3160812AS (scsi)
Disk /dev/sda: 160GB
Sector size (logical/physical): 512B/512B
Partition Table: msdos

Number  Start   End     Size    Type      File system  Flags
 1      32.3kB  107MB   107MB   primary   ext3         boot
 2      107MB   105GB   105GB   primary   ext3
 3      105GB   107GB   2147MB  primary   linux-swap
 4      107GB   160GB   52.9GB  extended       root
 5      107GB   133GB   26.2GB  logical   ext3
 6      133GB   133GB   107MB   logical   ext3
 7      133GB   160GB   26.6GB  logical               lvm
```

The first line contains the disk type, manufacturer, model number and interface, and the second line displays the disk label type. The remaining output below the fourth line shows the partition table.

In the partition table, the *Minor* number is the partition **number**. For example, the partition with minor number 1 corresponds to **/dev/sda1**. The **Start** and **End** values are in megabytes. Valid **Type** are metadata, free, primary, extended, or logical. The **Filesystem** is the file system type, which can be any of the following:

- ext2
- ext3
- fat16
- fat32
- hfs
- jfs
- linux-swap
- ntfs
- reiserfs

- hp-ufs
- sun-ufs
- xfs

If a **Filesystem** of a device shows no value, this means that its file system type is unknown.

The **Flags** column lists the flags set for the partition. Available flags are boot, root, swap, hidden, raid, lvm, or lba.

Note

To select a different device without having to restart **parted**, use the **select** command followed by the device name (for example, **/dev/sda**). Doing so allows you to view or configure the partition table of a device.

12.2. Creating a Partition

Warning

Do not attempt to create a partition on a device that is in use.

Procedure 12.1. Creating a partition

1. Before creating a partition, boot into rescue mode (or unmount any partitions on the device and turn off any swap space on the device).
2. Start **parted**, where **/dev/*sda*** is the device on which to create the partition:

```
# parted /dev/sda
```

3. View the current partition table to determine if there is enough free space:

```
# print
```

If there is not enough free space, you can resize an existing partition. Refer to Section 12.4, “Resizing a Partition” for details.

12.2.1. Making the Partition

From the partition table, determine the start and end points of the new partition and what partition type it should be. You can only have four primary partitions (with no extended partition) on a device. If you need more than four partitions, you can have three primary partitions, one extended partition, and multiple logical partitions within the extended. For an overview of disk partitions, refer to the appendix *An Introduction to Disk Partitions* in the Red Hat Enterprise Linux 7 *Installation Guide*.

For example, to create a primary partition with an ext3 file system from 1024 megabytes until 2048 megabytes on a hard drive type the following command:

```
# mkpart primary ext3 1024 2048
```

Note

If you use the **mkpartfs** command instead, the file system is created after the partition is created. However, **parted** does not support creating an ext3 file system. Thus, if you wish to create an ext3 file system, use **mkpart** and create the file system with the **mkfs** command as described later.

The changes start taking place as soon as you press **Enter**, so review the command before executing to it.

After creating the partition, use the **print** command to confirm that it is in the partition table with the correct partition type, file system type, and size. Also remember the minor number of the new partition so that you can label any file systems on it. You should also view the output of **cat /proc/partitions** after parted is closed to make sure the kernel recognizes the new partition.

The maximum number of partitions parted will create is 128. While the *GUID Partition Table* (GPT) specification allows for more partitions by growing the area reserved for the partition table, common practice used by parted is to limit it to enough area for 128 partitions.

12.2.2. Formatting and Labeling the Partition

To format and label the partition use the following procedure:

Procedure 12.2. Format and label the partition

1. The partition still does not have a file system. To create one use the following command:

   ```
   # /usr/sbin/mkfs -t ext3 /dev/sda6
   ```

   Warning

   Formatting the partition permanently destroys any data that currently exists on the partition.

2. Next, give the file system on the partition a label. For example, if the file system on the new partition is **/dev/sda6** and you want to label it **/work**, use:

   ```
   # e2label /dev/sda6 /work
   ```

By default, the installation program uses the mount point of the partition as the label to make sure the label is unique. You can use any label you want.

Afterwards, create a mount point (e.g. **/work**) as root.

12.2.3. Add to /etc/fstab

As root, edit the **/etc/fstab** file to include the new partition using the partition's UUID. Use the command **blkid -o list** for a complete list of the partition's UUID, or **blkid device** for individual device details.

The first column should contain **UUID=** followed by the file system's UUID. The second column should contain the mount point for the new partition, and the next column should be the file system type (for example, ext3 or swap). If you need more information about the format, read the man page with the command **man fstab**.

If the fourth column is the word **defaults**, the partition is mounted at boot time. To mount the partition without rebooting, as root, type the command:

```
mount /work
```

12.3. Removing a Partition

Warning

Do not attempt to remove a partition on a device that is in use.

Procedure 12.3. Remove a partition

1. Before removing a partition, boot into rescue mode (or unmount any partitions on the device and turn off any swap space on the device).
2. Start **parted**, where **/dev/*sda*** is the device on which to remove the partition:

   ```
   # parted /dev/sda
   ```
3. View the current partition table to determine the minor number of the partition to remove:

   ```
   # print
   ```
4. Remove the partition with the command **rm**. For example, to remove the partition with minor number 3:

   ```
   # rm 3
   ```

   The changes start taking place as soon as you press **Enter**, so review the command before committing to it.
5. After removing the partition, use the **print** command to confirm that it is removed from the partition table. You should also view the output of **/proc/partitions** to make sure the kernel knows the partition is removed.

   ```
   # cat /proc/partitions
   ```
6. The last step is to remove it from the **/etc/fstab** file. Find the line that declares the removed partition, and remove it from the file.

12.4. Resizing a Partition

Before resizing a partition, back up the information on the file system.

Procedure 12.4. Resize a partition

1. Unmount the device.

```
~]# umount /dev/vda
```

2. Run **fdisk *device_name***.

```
~]# fdisk /dev/vda
Welcome to fdisk (util-linux 2.23.2).

Changes will remain in memory only, until you decide to write
them. Be careful before using the write command.

Command (m for help):
```

3. Check the partition number to be deleted with the **p** option. The partitions are listed under the heading 'Device'.

```
Command (m for help): p
Disk /dev/vda: 16.1 GB, 16106127360 bytes, 31457280 sectors
Units = sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disk label type: dos
Disk identifier: 0x0006d09a

Device    Boot      Start         End      Blocks   Id  System
/dev/vda1   *        2048     1026047      512000   83  Linux
/dev/vda2         1026048    31457279    15215616   8e  Linux LVM
```

Important

Red Hat only supports the extension or resizing of LVM partitions.

4. Use the **d** option to delete a partition. If there is more than one partition available, **fdisk** will prompt for which one to delete.

```
Command (m for help): d
Partition number (1,2, default 2): 2
Partition 2 is deleted
```

5. Use the **n** option to create a new partition. Follow the prompts and ensure enough space is allowed for any future resizing that is needed. It is possible to specify a set, human-readable size instead of using sectors if this is preferred.

Note

It is recommended to follow **fdisk**'s default options for the default values and partition sizes (for example, the first partition sectors).

```
Command (m for help): n
```

```
Partition type:
   p   primary (1 primary, 0 extended, 3 free)
   e   extended
Select (default p): *Enter*
Using default response p
Partition number (2-4, default 2): *Enter*
First sector (1026048-31457279, default 1026048): *Enter*
Using default value 1026048
Last sector, +sectors or +size{K,M,G} (1026048-31457279, default
31457279): +500M
Partition 2 of type Linux and of size 500 MiB is set
```

6. Set the partition type to LVM.

```
Command (m for help): t
Partition number (1,2, default 2): *Enter*
Hex code (type L to list all codes): 8e
Changed type of partition 'Linux' to 'Linux LVM'
```

7. Write the changes with the **w** option when certain they are correct.

Important

Errors in this process that are written could cause instability with the selected partition.

8. Run **e2fsck** on the device to check for consistency.

```
~]# e2fsck /dev/vda
e2fsck 1.41.12 (17-May-2010)
Pass 1:Checking inodes, blocks, and sizes
Pass 2:Checking directory structure
Pass 3:Checking directory connectivity
Pass 4:Checking reference counts
Pass 5:Checking group summary information
ext4-1:11/131072 files (0.0% non-contiguous),27050/524128 blocks
```

9. Mount the device.

```
~]# mount /dev/vda
```

For more information refer to the following references:

man fdisk

The man page for **fdisk**. It has basic information about what **fdisk** is and what it supports.

The m option within fdisk

This option lists all available commands within **fdisk**.

Chapter 13. Creating and Maintaining Snapshots with Snapper

A snapshot volume is a point in time copy of a target volume that provides a way to revert a file system back to an earlier state. Snapper is a command-line tool to create and maintain snapshots for btrfs and thinly-provisioned LVM file systems. It provides snapshot functionality as the file system specific tools, with some useful extras, such as comparing changes between two snapshots.

Note

The btrfs tools and file system are provided as a Technology Preview and should not be used on production systems.

13.1. Initial Snapper Setup

Snapper requires discrete configuration files for each volume it operates on. These must be set up manually. By default, only the root user is allowed to perform snapper commands. To allow a user or group access to snapper features requiring root privilege, please refer to Section 13.2, “Allow Users and Groups to Execute Snapper Commands”. To create a configuration file, use the following procedure.

Note

The btrfs tools and file system are provided as a Technology Preview and should not be used on production systems.

Procedure 13.1. Create a Snapper Configuration File

1. Create or choose either:
   - A thinly-provisioned logical volume with a Red Hat supported file system on top of it, or
   - A btrfs subvolume.
2. Mount the file system.
3. Create the configuration file that defines this volume.

   For LVM2:

   ```
   # snapper -c config_name create-config -f "lvm(fs_type)" /mount-point
   ```

   For btrfs:

   ```
   ~]# snapper -c config_name create-config -f btrfs /mount-point
   ```

   The **-c *config_name*** option specifies the name of the configuration file.

   The **create-config** tells snapper to create a configuration file.

The **-f *file_system*** tells snapper what file system to use; if this is omitted snapper will attempt to detect the file system.

The ***/mount-point*** is where the subvolume or thinly-provisioned LVM2 file system is mounted.

For example, to create a configuration file called **lvm_config** on an LVM2 subvolume with an ext4 file system, mounted at **/lvm_mount**, use:

```
# snapper -c lvm_config create-config -f "lvm(ext4)" /lvm_mount
```

Alternatively, to create a configuration file called **btrfs_config**, on a btrfs subvolume that is mounted at **/btrfs_mount**, use the following command:

```
# snapper -c btrfs_config create-config -f btrfs /btrfs_mount
```

These configuration files are stored in **/etc/snapper/configs/**.

13.2. Allow Users and Groups to Execute Snapper Commands

To allow a user or group other than root to use some snapper commands, changes can be made in the configuration file (created in Section 13.1, “Initial Snapper Setup”).

Important

Although it is possible to add elevated permissions to otherwise unprivileged users or groups it is not recommended. Such a configuration bypasses SELinux and could pose a security risk. You should review these capabilities with your Security Team and consider using a **sudo** infrastructure instead.

To allow a user or group snapper permissions, add the **ALLOW_USERS=** and **ALLOW_GROUPS=** lines to the configuration file. The commands that this will allow are:

- mount
- umount
- status
- create
- delete
- list
- modify
- cleanup

For example, to allow the user **user1** and the group **snapper_group** privileged access, the configuration file will look like this:

```
# cat /etc/snapper/configs/lvm_config
```

```
# subvolume to snapshot
SUBVOLUME="/lvmmount"

# filesystem type
FSTYPE="lvm(ext4)"

# users and groups allowed to work with config
ALLOW_USERS="user1"
ALLOW_GROUPS="snapper_group"

...
```

13.3. Creating a Snapper Snapshot

There are three kinds of snapshots that snapper can create: pre, post, and single.

Pre Snapshot

A pre snapshot serves as a point of origin for a post snapshot. The two are closely tied and designed to track file system modification between the two points. The pre snapshot must be created before the post snapshot.

Post Snapshot

A post snapshot serves as the end point to the pre snapshot. The coupled pre and post snapshots define a range for comparison. By default, every new snapper volume is configured to create a background comparison after a related post snapshot is created successfully.

Single Snapshot

A single snapshot is a standalone snapshot created at a specific moment. These can be used to track a timeline of modifications and have a general point to return to at a later date.

13.3.1. Create a Pre and Post Snapshot Pair

To create a pre and post snapshot pair with snapper, the first step is to create the pre snapshot.

13.3.1.1. Create a Pre Snapshot

To create a pre snapshot, use the following command:

```
# snapper -c config_name create -t pre
```

The **-c *config_name*** option creates a snapshot according to the specifications in the named configuration file. If the configuration file does not yet exist, refer to Section 13.1, “Initial Snapper Setup”.

The **create -t** option specifies what type of snapshot to create. Accepted entries are pre, post, or single.

For example, to create a pre snapshot using the **lvm_config** configuration file, as created in Section 13.1, “Initial Snapper Setup”, use the following command:

```
# snapper -c SnapperExample create -t pre -p
1
```

Note

For the purposes of this example, the option -p is used to print the number of the snapshot created but it is safe to not include this option.

13.3.1.2. Create a Post Snapshot

A post snapshot is the end point of the snapshot and should be created after the parent pre snapshot by following the instructions in Section 13.3.1.1, “Create a Pre Snapshot”.

Procedure 13.2. Create a Post Snapshot with Snapper

1. To create a post snapshot, first find the number of the pre snapshot it will be linked to with the **`list`** command.

   ```
   # snapper -c config_name list
   ```

   For example, to display the list of snapshots created using the configuration file **`btrfs_config`**, use the following:

   ```
   # snapper -c btrfs_config list
   Type   | # | Pre # | Date                | User | Cleanup  |
   Description | Userdata
   -------+---+-------+---------------------+------+----------+--------
   -----+---------
   single | 0 |       |                     | root |          | current
   |
   pre    | 1 |       | Mon 06<...> | root |          |             |
   ```

   The output above shows that the pre snapshot is number 1.

2. Next, use the following command to create a post snapshot that is linked to a previously created pre snapshot:

   ```
   # snapper -c config_file create -t post --pre-num
   pre_snapshot_number
   ```

   Here, the **`create -t`** option specifies post to create a post snapshot.

   The **`--pre-num`** option specifies the corresponding pre snapshot.

   For example, to create a post snapshot using the **`btrfs_config`** configuration file and is linked to pre snapshot number 1, use the following command:

   ```
   # snapper -c btrfs_config create -t post --pre-num 1 -p
   2
   ```

Note

For the purposes of this example, the option -p is used to print the number of the snapshot created. This can usually be left off but its use will make the example easier to follow.

3. Now the pre and post snapshots 1 and 2 are created and paired. Verify this with another **`list`** command. For example:

```
# snapper -c btrfs_config list
Type   | # | Pre # | Date                | User | Cleanup  |
Description | Userdata
-------+---+-------+---------------------+------+----------+--------
-----+---------
single | 0 |       |                     | root |          | current
|
pre    | 1 |       | Mon 06<...> | root |          |             |
post   | 2 | 1     | Mon 06<...> | root |          |             |
```

It is also possible to wrap a command within a pre and post snapshot which can be useful when testing.

Procedure 13.3. Wrap a Command in Pre and Post Snapshots

1. To wrap a command in pre and post snapshots, use the following command:

```
# snapper -c btrfs_config create --command "command_to_be_tracked"
```

For example, to track the creation of the file **`/btrfs_mount/hello_file`** use the following command:

```
# snapper -c btrfs_config create --command "echo Hello >
/btrfs/hello_file"
```

2. To verify this, use the **`status`**.

```
# snapper -c config_file status
first_snapshot_number..second_snapshot_number
```

For example, to track the changes made in the first step use the following command:

```
# snapper -c btrfs_config status 3..4
+..... /btrfs_mount/hello_file
```

Remember, the **`list`** command can be used to verify what a snapshot's number is.

For more information on the **`status`** command, refer to Section 13.4, “Track Changes Between Snapper Snapshots”

There is no guarantee that the command in the above example is the only thing the snapshots capture; snapper will also record anything that is modified by the system, not just what a user modifies.

13.3.2. Create a Single Snapper Snapshot

Creating a single snapper snapshot is similar to creating a pre or post snapshot, only the **create -t** option specifies single. The single snapshot is used to create a single snapshot in time without having it relate to any others.

Use the following command to create a single snapshot:

```
# snapper -c config_name create -t single
```

For example, the following command will create a single snapshot using the **btrfs_config** configuration file.

```
# snapper -c SnapperExample create -t single
```

Note

Despite the fact that single snapshots are not specifically designed to track changes, snapper is able to create a comparison between any two snapshots by explicit demand of the user (that is, by **snapper diff**, **xadiff**, or **status** command). For more information on these commands, refer to Section 13.4, “Track Changes Between Snapper Snapshots”.

13.4. Track Changes Between Snapper Snapshots

There are three commands used to track the changes made to a subvolume between snapshots. These are **status**, **diff**, and **xadiff**.

status

The **status** command shows a list of files and directories that have been created, modified, or deleted between two snapshots.

Refer to Section 13.4.1, “Comparing Changes with the **status** Command” for more information.

diff

The **diff** command shows a diff of modified files and directories between two snapshots.

Refer to Section 13.4.2, “Comparing changes with the **diff** command” for more information.

xadiff

The **xadiff** command compares how the extended attributes of a file or directory have changed between two snapshots.

Refer to Section 13.4.3, “Comparing changes with the **xadiff** command” for more information.

13.4.1. Comparing Changes with the status Command

The **status** command shows a list of files and directories that have been created, modified, or deleted between two snapshots.

Use the following command to display the status of files between two snapshots:

```
# snapper -c config_file status
first_snapshot_number..second_snapshot_number
```

Remember, the number of snapshots can be found with the **list** command.

For example, the following command displays the changes made between snapshot 1 and 2, using the configuration file **btrfs_config**.

```
snapper -c btrfs_config status 1..2
tp.... /btrfs_mount/dir1
-..... /btrfs_mount/dir1/file_a
c.ug.. /btrfs_mount/file2
+..... /btrfs_mount/file3
....x. /btrfs_mount/file4
cp..xa /btrfs_mount/file5
```

The letters and dots in the first part of the output should be read as columns.

```
+..... /btrfs_mount/file3
||||||
123456
```

Column 1, as shown below, indicates any modification in the file's (directory entry) type. Possible values are:

Column 1

Output	Meaning
.	Nothing has changed.
+	File created.
-	File deleted.
c	Content changed.
t	Type of directory entry has changed (for example, a former symbolic link has changed to a regular file with the same file name).

Column 2, as shown below, indicates any changes in the file's permissions. Possible values are:

Column 2

Output	Meaning
.	No permissions changed.
p	Permissions changed.

Column 3, as shown below, indicates any changes in the user ownership. Possible values are:

Column 3

Output	Meaning
.	No user ownership changed.
u	User ownership has changed.

Column 4, as shown below, indicates any changes in the group ownership. Possible values are:

Column 4

Output	Meaning
.	No group ownership changed.
g	Group ownership has changed.

Column 5, as shown below, indicates any changes in the extended attributes. Possible values are:

Column 5

Output	Meaning
.	No extended attributes changed.
x	Extended attributes changed.

Column 6, as shown below, indicates any changes in the access control lists (ACLs). Possible values are:

Column 6

Output	Meaning
.	No ACLs changed.
a	ACLs modified.

13.4.2. Comparing changes with the `diff` command

The **`diff`** command shows the changes of modified files and directories between two snapshots. The following command demostrates:

```
        # snapper -c config_name diff
first_snapshot_number..second_snapshot_number
```

Remember, the number of snapshots can be found with the **`list`** command.

For example, to compare the changes made in files between snapshot 1 and snapshot 2 that were made using the **`btrfs_config`** configuration file, use the following command:

```
# snapper -c btrfs_config diff 1..2
--- /btrfs_mount/.snapshots/13/snapshot/file4 19<...>
+++ /btrfs_mount/.snapshots/14/snapshot/file4 20<...>
@@ -0,0 +1 @@
+words
```

The above output shows that **`file4`** had been modified to add "words" into the file.

13.4.3. Comparing changes with the `xadiff` command

The **xadiff** command compares how the extended attributes of a file or directory have changed between two snapshots. To do so, use the following command:

```
        # snapper -c config_name xadiff
first_snapshot_number..second_snapshot_number
```

Remember, the number of snapshots can be found with the **list** command.

For example, to show the xadiff output between snapshot number 1 and snapshot number 2 that were made using the **btrfs_config** configuration file, the command would be:

```
        # snapper -c btrfs_config xadiff 1..2
```

13.5. Reverse Changes in Between Snapshots

To reverse changes made between two existing snapper snapshots, the **undochange** command is used in the following format: **snapper -c *config_name* undochange *1..2*** where the 1 is the first snapshot and 2 is the second snapshot.

Important

This will not revert the snapper volume back to its original state and does not provide data consistency. Any file modification that occurs outside of the specified range (for example, after snapshot 2) will remain unchanged after reverting back (for example, to the state of snapshot 1). For example, should the **undochange** be run to undo the creation of a user, any files owned by that user may still remain.

There is also no mechanism to ensure file consistency as a snapshot is made, so any inconsistencies that already exist can be transfered back to the snapshot when the **undochange** command is used.

To understand how the **undochange** command works, consider the following diagram:

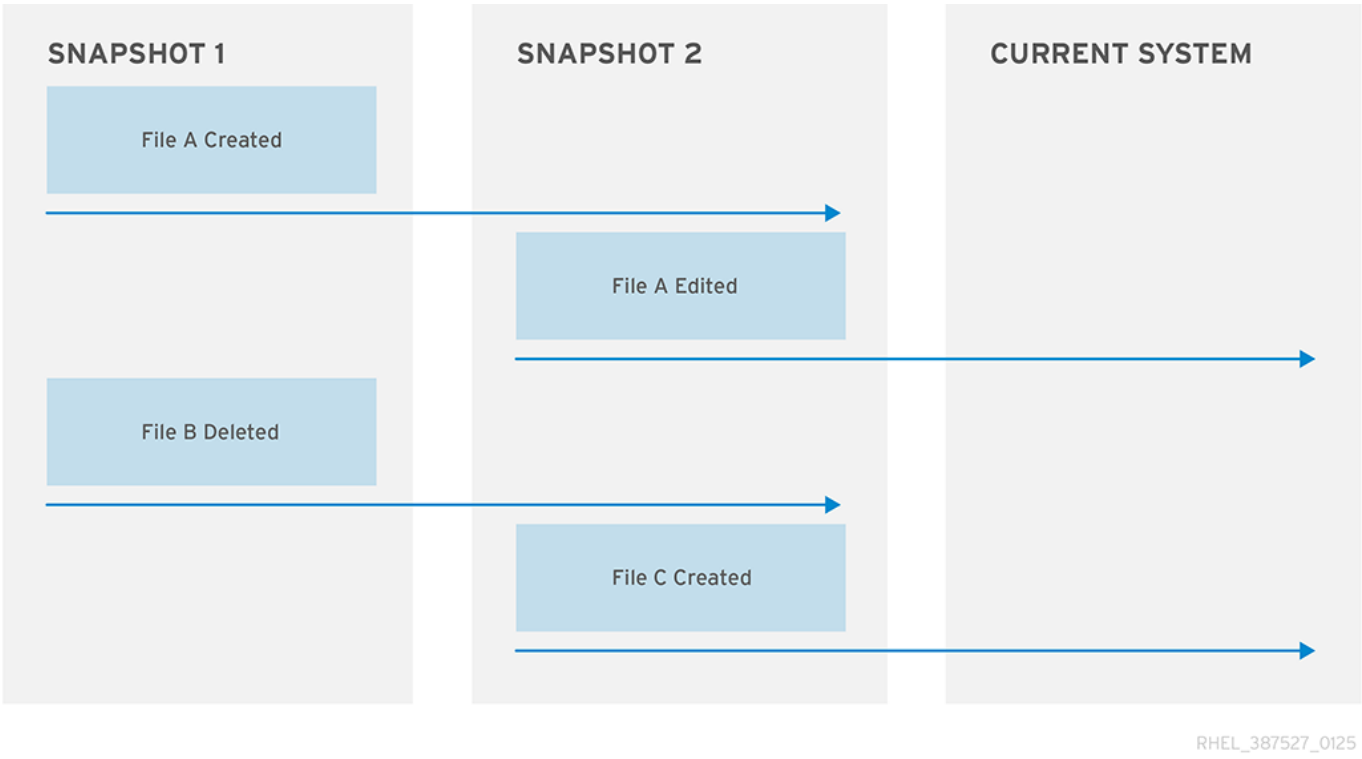


Figure 13.1. Snapper Status Over Time

In the above diagram it shows the point in time where **snapshot_1** is created, **file_a** is created, then **file_b** deleted. **Snapshot_2** is then created, after which **file_a** is edited and **file_c** is created. This is now the current state of the system. The current system has an edited version of **file_a**, no **file_b**, and a newly created **file_c**

When the **undochange** is called, snapper generates a list of modified files between the first listed snapshot and the second. In the above diagram, should the command be **snapper -c SnapperExample undochange 1..2**, snapper will create a list of modified files (that is, **file_a** is created; **file_b** is deleted) and apply them to the current system. Therefore, the current system will not have **file_a** (as it has yet to be created when **snapshot_1** was created), **file_b** will exist (copied from **snapshot_1** into the current system), and **file_c** will exist, as its creation was outside the specified time. Be aware that, should **file_b** and **file_c** conflict, the system could become corrupted.

It is also possible for the command to be **snapper -c SnapperExample undochange 2..1**. In this case the current system will replace the edited version of **file_a** with one copied from **snapshot_1**, thus undoing the editing that took place on that file after **snapshot_2** was created.

13.6. Delete a Snapshot

To delete a snapshot, use the following command:

```
~]# snapper -c config_name delete snapshot_number
```

This can then be verified with the **list** command.

Chapter 14. Swap Space

Swap space in Linux is used when the amount of physical memory (RAM) is full. If the system needs more memory resources and the RAM is full, inactive pages in memory are moved to the swap space. While swap space can help machines with a small amount of RAM, it should not be considered a replacement for more RAM. Swap space is located on hard drives, which have a slower access time than physical memory. Swap space can be a dedicated swap partition (recommended), a swap file, or a combination of swap partitions and swap files. Note that *Btrfs* does *not* support swap space.

In years past, the recommended amount of swap space increased linearly with the amount of RAM in the system. However, modern systems often include hundreds of gigabytes of RAM. As a consequence, recommended swap space is considered a function of system memory workload, not system memory.

Table 14.1, “Recommended System Swap Space” provides the recommended size of a swap partition depending on the amount of RAM in your system and whether you want sufficient memory for your system to hibernate. The recommended swap partition size is established automatically during installation. To allow for hibernation, however, you need to edit the swap space in the custom partitioning stage.

Recommendations in Table 14.1, “Recommended System Swap Space” are especially important on systems with low memory (1 GB and less). Failure to allocate sufficient swap space on these systems can cause issues such as instability or even render the installed system unbootable.

Table 14.1. Recommended System Swap Space

Amount of RAM in the system	Recommended swap space	Recommended swap space if allowing for hibernation
⩽ 2 GB	2 times the amount of RAM	3 times the amount of RAM
> 2 GB – 8 GB	Equal to the amount of RAM	2 times the amount of RAM
> 8 GB – 64 GB	At least 4 GB	1.5 times the amount of RAM
> 64 GB	At least 4 GB	Hibernation not recommended

At the border between each range listed in Table 14.1, “Recommended System Swap Space”, for example a system with 2 GB, 8 GB, or 64 GB of system RAM, discretion can be exercised with regard to chosen swap space and hibernation support. If your system resources allow for it, increasing the swap space may lead to better performance. A swap space of at least 100 GB is recommended for systems with over 140 logical processors or over 3 TB of RAM.

Note that distributing swap space over multiple storage devices also improves swap space performance, particularly on systems with fast drives, controllers, and interfaces.

Important

File systems and LVM2 volumes assigned as swap space *should not* be in use when being modified. Any attempts to modify swap fail if a system process or the kernel is using swap space. Use the **free** and **cat /proc/swaps** commands to verify how much and where swap is in use.

You should modify swap space while the system is booted in **rescue** mode, see Booting Your Computer in Rescue Mode in the *Red Hat Enterprise Linux 7 Installation Guide*. When prompted to mount the file system, select **Skip**.

14.1. Adding Swap Space

Sometimes it is necessary to add more swap space after installation. For example, you may upgrade the amount of RAM in your system from 1 GB to 2 GB, but there is only 2 GB of swap space. It might be advantageous to increase the amount of swap space to 4 GB if you perform memory-intense operations or run applications that require a large amount of memory.

You have three options: create a new swap partition, create a new swap file, or extend swap on an existing LVM2 logical volume. It is recommended that you extend an existing logical volume.

14.1.1. Extending Swap on an LVM2 Logical Volume

By default, Red Hat Enterprise Linux 7 uses all available space during installation. If this is the case with your system, then you must first add a new physical volume to the volume group used by the swap space.

After adding additional storage to the swap space's volume group, it is now possible to extend it. To do so, perform the following procedure (assuming **/dev/VolGroup00/LogVol01** is the volume you want to extend by 2 GB):

Procedure 14.1. Extending Swap on an LVM2 Logical Volume

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol01
```

2. Resize the LVM2 logical volume by 2 GB:

```
# lvresize /dev/VolGroup00/LogVol01 -L +2G
```

3. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol01
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol01
```

To test if the logical volume was successfully extended, use **cat /proc/swaps** or **free** to inspect the swap space.

14.1.2. Creating an LVM2 Logical Volume for Swap

To add a swap volume group (assuming **/dev/VolGroup00/LogVol02** is the swap volume you want to add):

1. Create the LVM2 logical volume of size 2 GB:

```
# lvcreate VolGroup00 -n LogVol02 -L 2G
```

2. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol02
```

3. Add the following entry to the **/etc/fstab** file:

```
# /dev/VolGroup00/LogVol02 swap swap defaults 0 0
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol02
```

To test if the logical volume was successfully created, use **cat /proc/swaps** or **free** to inspect the swap space.

14.1.3. Creating a Swap File

To add a swap file:

Procedure 14.2. Add a swap file

1. Determine the size of the new swap file in megabytes and multiply by 1024 to determine the number of blocks. For example, the block size of a 64 MB swap file is 65536.
2. At a shell, type the following command with **count** being equal to the desired block size:

```
# dd if=/dev/zero of=/swapfile bs=1024 count=65536
```

3. Setup the swap file with the command:

```
# mkswap /swapfile
```

4. Change the security of the swapfile so it is not world readable.

```
# chmod 0600 /swapfile
```

5. To enable the swap file immediately but not automatically at boot time:

```
# swapon /swapfile
```

6. To enable it at boot time, edit **/etc/fstab** to include the following entry:

   ```
   /swapfile swap swap defaults 0 0
   ```

   The next time the system boots, it enables the new swap file.

To test if the new swap file was successfully created, use **cat /proc/swaps** or **free** to inspect the swap space.

14.2. Removing Swap Space

Sometimes it can be prudent to reduce swap space after installation. For example, say you downgraded the amount of RAM in your system from 1 GB to 512 MB, but there is 2 GB of swap space still assigned. It might be advantageous to reduce the amount of swap space to 1 GB, since the larger 2 GB could be wasting disk space.

You have three options: remove an entire LVM2 logical volume used for swap, remove a swap file, or reduce swap space on an existing LVM2 logical volume.

14.2.1. Reducing Swap on an LVM2 Logical Volume

To reduce an LVM2 swap logical volume (assuming **/dev/VolGroup00/LogVol01** is the volume you want to reduce):

Procedure 14.3. Reducing an LVM2 swap logical volume

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol01
```

2. Reduce the LVM2 logical volume by 512 MB:

```
# lvreduce /dev/VolGroup00/LogVol01 -L -512M
```

3. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol01
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol01
```

To test if the swap's logical volume size was successfully reduced, use **cat /proc/swaps** or **free** to inspect the swap space.

14.2.2. Removing an LVM2 Logical Volume for Swap

To remove a swap volume group (assuming **/dev/VolGroup00/LogVol02** is the swap volume you want to remove):

Procedure 14.4. Remove a swap volume group

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol02
```

2. Remove the LVM2 logical volume of size 512 MB:

```
# lvremove /dev/VolGroup00/LogVol02
```

3. Remove the following entry from the **/etc/fstab** file:

```
/dev/VolGroup00/LogVol02 swap swap defaults 0 0
```

To test if the logical volume size was successfully removed, use **cat /proc/swaps** or **free** to inspect the swap space.

14.2.3. Removing a Swap File

To remove a swap file:

Procedure 14.5. Remove a swap file

1. At a shell prompt, execute the following command to disable the swap file (where **/swapfile** is the swap file):

```
# swapoff -v /swapfile
```

2. Remove its entry from the **/etc/fstab** file.

3. Remove the actual file:

```
# rm /swapfile
```

14.3. Moving Swap Space

To move swap space from one location to another, follow the steps for removing swap space, and then follow the steps for adding swap space.

Chapter 15. System Storage Manager (SSM)

System Storage Manager (SSM) provides a command line interface to manage storage in various technologies. Storage systems are becoming increasingly complicated through the use of Device Mappers (DM), Logical Volume Managers (LVM), and Multiple Devices (MD). This creates a system that is not user friendly and makes it easier for errors and problems to arise. SSM alleviates this by creating a unified user interface. This interface allows users to run complicated systems in a simple manner. For example, to create and mount a new file system without SSM, there are five commands that must be used. With SSM only one is needed.

This chapter will explain how SSM interacts with various back ends, then detail some common use cases.

15.1. SSM Backends

SSM uses a core abstraction layer in **`ssmlib/main.py`** which complies with the device, pool, and volume abstraction, ignoring the specifics of the underlying technology. Backends can be registered in **`ssmlib/main.py`** to handle specific storage technology methods, such as **`create`**, **`snapshot`**, or to **`remove`** volumes and pools.

There are already several backends registered in SSM. The following sections will give basic information on them as well as definitions on how they handle pools, volumes, snapshots, and devices.

15.1.1. BTRFS Backend

BTRFS, a file system with many advanced features, is used as a volume management backend in SSM. Pools, volumes, and snapshots can be created with the BTRFS backend.

15.1.1.1. BTRFS Pool

The BTRFS file system itself is the pool. It can be extended by adding more devices or shrunk by removing devices. SSM creates a BTRFS file system when a BTRFS pool is created. This means that every new BTRFS pool has one volume of the same name as the pool which cannot be removed without removing the entire pool. The default BTRFS pool name is **`btrfs_pool`**.

The name of the pool is used as the file system label. If there is already an existing BTRFS file system in the system without a label, the BTRFS pool will generate a name for internal use in the format of **`btrfs_`*`device_base_name`***.

15.1.1.2. BTRFS Volume

Volumes created after the first volume in a pool are the same as sub-volumes. SSM will temporarily mount the BTRFS file system if it is unmounted in order to create a sub-volume.

The name of a volume is used as the subvolume path in the BTRFS file system. For example, a subvolume displays as **`/dev/lvm_pool/lvol001`**. Every object in this path must exist in order for the volume to be created. Volumes can also be referenced with its mount point.

15.1.1.3. BTRFS Snapshot

Snapshots can be taken of any BTRFS volume in the system with SSM. Be aware that BTRFS does not distinguish between subvolumes and snapshots. While this means that SSM cannot recognize the BTRFS snapshot destination, it will try to recognize special name formats. If the name specified

when creating the snapshot does the specific pattern, the snapshot will not be recognized and instead be listed as a regular BTRFS volume.

15.1.1.4. BTRFS Device

BTRFS does not require any special device to be created on.

15.1.2. LVM Backend

Pools, volumes, and snapshots can be created with LVM. The following definitions are from an LVM point of view.

15.1.2.1. LVM Pool

LVM pool is the same as an LVM volume group. This means that grouping devices and new logical volumes can be created out of the LVM pool. The default LVM pool name is **`lvm_pool`**.

15.1.2.2. LVM Volume

An LVM volume is the same as an ordinary logical volume.

15.1.2.3. LVM Snapshot

When a snapshot is created from the LVM volume a new **`snapshot`** volume is created which can then be handled just like any other LVM volume. Unlike BTRFS, LVM is able to distinguish snapshots from regular volumes so there is no need for a snapshot name to match a particular pattern.

15.1.2.4. LVM Device

SSM makes the need for an LVM backend to be created on a physical device transparent for the user.

15.1.3. Crypt

The crypt backend in SSM uses **`cryptsetup`** and **`dm-crypt target`** to manage encrypted volumes. Crypt backends can be used as a regular backend for creating encrypted volumes on top of regular block devices (or on other volumes such as LVM or MD volumes), or to create encrypted LVM volumes in a single steps.

Only volumes can be created with a crypt backend; pooling is not supported and it does not require special devices.

The following sections define volumes and snapshots from the crypt point of view.

15.1.3.1. Crypt Volume

Crypt volumes are created by **`dm-crypt`** and represent the data on the original encrypted device in an unencrypted form. It does not support RAID or any device concatenation.

Two modes, or extensions, are supported: luks and plain. Luks is used by default. For more information on the extensions, refer to **`man cryptsetup`**.

15.1.3.2. Crypt Snapshot

While the crypt backend does not support snapshotting, if the encrypted volume is created on top of an LVM volume, the volume itself can be snapshotted. The snapshot can then be opened by using

cryptsetup.

15.1.4. Multiple Devices (MD)

MD backend is currently limited to only gathering the information about MD volumes in the system.

15.2. Common SSM Tasks

The following sections will go through basic use cases covering how to install SSM then display information about all detected devices, pools, and volumes. Next, a pool will be created with two volumes and an XFS file system. The file system will then be checked for consistency, then a volume will be increased in size. Then a snapshot will be created. Finally one of the volumes will be removed.

15.2.1. SSM Installation

To install SSM use the following command:

```
# yum install system-storage-manager
```

There are several backends that are enabled only if the supporting packages are installed:

- The LVM backend requires the **lvm2** package.
- The BTRFS backend requires the **btrfs-progs** package.
- The Crypt backend requires the **device-mapper** and **cryptsetup** packages.

15.2.2. Show information about all detected devices

Displaying information about all detected devices, pools, volumes, and snapshots is done with the **list** command. Running the **ssm list** with no options will display the following output:

```
~]# ssm list
----------------------------------------------------------
Device        Free      Used      Total  Pool  Mount point
----------------------------------------------------------
/dev/sda                          2.00 GB        PARTITIONED
/dev/sda1                        47.83 MB        /test
/dev/vda                         15.00 GB        PARTITIONED
/dev/vda1                       500.00 MB        /boot
/dev/vda2  0.00 KB  14.51 GB   14.51 GB  rhel
----------------------------------------------------------
------------------------------------------------
Pool  Type  Devices     Free      Used     Total
------------------------------------------------
rhel  lvm   1        0.00 KB  14.51 GB  14.51 GB
------------------------------------------------
-------------------------------------------------------------------------
---------
Volume          Pool  Volume size  FS     FS size       Free  Type
Mount point
-------------------------------------------------------------------------
---------
/dev/rhel/root  rhel     13.53 GB  xfs   13.52 GB    9.64 GB  linear  /
```

```
/dev/rhel/swap  rhel   1000.00 MB                                  linear
/dev/sda1                47.83 MB  xfs   44.50 MB   44.41 MB  part
/test
/dev/vda1               500.00 MB  xfs  496.67 MB  403.56 MB  part
/boot
--------------------------------------------------------------------------
---------
```

This display can be further narrowed down by using arguments to specify what should be displayed. The list of available options can be found with the **ssm list --help** command.

Note

Depending on the argument given, SSM may not display everything.

- Running the **devices** or **dev** argument will omit some devices. CDRoms and DM/MD devices, for example, are intentionally hidden as they are listed as volumes.
- Some backends do not support snapshots and cannot distinguish between a snapshot and a regular volume. Running the **snapshot** argument on one of these backends will cause SSM to attempt to recognize the volume name in order to identify a snapshot. If the SSM regular expression does not match the snapshot pattern then the snapshot will not be recognized.
- With the exception of the main BTRFS volume (the file system itself), any unmounted BTRFS volumes will not be shown.

15.2.3. Create a new pool, logical volume, and file system

In this section, a new pool will be created with a default name. It will have the devices **/dev/vdb** and **/dev/vdc**, a logical volume of 1G, and an XFS file system.

The command to create this scenario is **ssm create --fs xfs -s 1G /dev/vdb /dev/vdc**. The following options are used:

- The **--fs** option specifies the required file system type. Current supported file system types are:
  - ext3
  - ext4
  - xfs
  - btrfs
- The **-s** specifies the size of the logical volume. The following suffixes are supported to define units:
  - **K** or **k** for kilobytes
  - **M** or **m** for megabytes
  - **G** or **g** for gigabytes
  - **T** or **t** for terabytes
  - **P** or **p** for petabytes

- **E** or **e** for exabytes

- The two listed devices, **/dev/vdb** and **/dev/vdc**, are the two devices I wish to create.

```
~]# ssm create --fs xfs -s 1G /dev/vdb /dev/vdc
  Physical volume "/dev/vdb" successfully created
  Physical volume "/dev/vdc" successfully created
  Volume group "lvm_pool" successfully created
  Logical volume "lvol001" created
```

There are two other options for the **ssm command** that may be useful. The first is the **-p *pool*** command. This specifies the pool the volume is to be created on. If it does not yet exist, then SSM will create it. This was omitted in the above example which caused SSM to use the default name **lvm_pool**. However, to use a specific name to fit in with any existing naming conventions, the **-p** option should be used.

The second useful option is the **-n *name*** command. This names the newly created logical volume. As with the **-p**, this is needed in order to use a specific name to fit in with any existing naming conventions.

An example of these two options being used follows:

```
~]# ssm create --fs xfs -p new_pool -n XFS_Volume /dev/vdd
  Volume group "new_pool" successfully created
  Logical volume "XFS_Volume" created
```

SSM has now created two physical volumes, a pool, and a logical volume with the ease of only one command.

15.2.4. Check a file system's consistency

The **ssm check** command checks the file system consistency on the volume. It is possible to specify multiple volumes to check. If there is no file system on the volume, then the volume will be skipped.

To check all devices in the volume **lvol001**, run the command **ssm check /dev/lvm_pool/lvol001**.

```
~]# ssm check /dev/lvm_pool/lvol001
Checking xfs file system on '/dev/mapper/lvm_pool-lvol001'.
Phase 1 - find and verify superblock...
Phase 2 - using internal log
        - scan filesystem freespace and inode maps...
        - found root inode chunk
Phase 3 - for each AG...
        - scan (but don't clear) agi unlinked lists...
        - process known inodes and perform inode discovery...
        - agno = 0
        - agno = 1
        - agno = 2
        - agno = 3
        - agno = 4
        - agno = 5
        - agno = 6
        - process newly discovered inodes...
Phase 4 - check for duplicate blocks...
        - setting up duplicate extent list...
```

```
        - check for inodes claiming duplicate blocks...
        - agno = 0
        - agno = 1
        - agno = 2
        - agno = 3
        - agno = 4
        - agno = 5
        - agno = 6
No modify flag set, skipping phase 5
Phase 6 - check inode connectivity...
        - traversing filesystem ...
        - traversal finished ...
        - moving disconnected inodes to lost+found ...
Phase 7 - verify link counts...
No modify flag set, skipping filesystem flush and exiting.
```

15.2.5. Increase a volume's size

The **ssm resize** command changes the size of the specified volume and file system. If there is no file system then only the volume itself will be resized.

For this example, we currently have one logical volume on **/dev/vdb** that is 900MB called **lvol001**.

```
~]# ssm list
----------------------------------------------------------------------
Device           Free       Used      Total  Pool      Mount point
----------------------------------------------------------------------
/dev/vda                             15.00 GB            PARTITIONED
/dev/vda1                           500.00 MB            /boot
/dev/vda2    0.00 KB   14.51 GB   14.51 GB  rhel
/dev/vdb   120.00 MB  900.00 MB    1.00 GB  lvm_pool
/dev/vdc                             1.00 GB
----------------------------------------------------------------------
--------------------------------------------------------
Pool      Type  Devices       Free       Used       Total
--------------------------------------------------------
lvm_pool  lvm   1        120.00 MB  900.00 MB  1020.00 MB
rhel      lvm   1          0.00 KB   14.51 GB    14.51 GB
--------------------------------------------------------
------------------------------------------------------------------------
--------------------
Volume                 Pool      Volume size  FS     FS size       Free
Type    Mount point
------------------------------------------------------------------------
--------------------
/dev/rhel/root         rhel        13.53 GB  xfs   13.52 GB    9.64 GB
linear  /
/dev/rhel/swap         rhel       1000.00 MB
linear
/dev/lvm_pool/lvol001  lvm_pool    900.00 MB  xfs  896.67 MB  896.54 MB
linear
```

```
/dev/vda1                              500.00 MB  xfs  496.67 MB  403.56 MB
part    /boot
------------------------------------------------------------------------------
--------------------
```

The logical volume needs to be increased by another 500MB. To do so we will need to add an extra device to the pool:

```
~]# ssm resize -s +500M /dev/lvm_pool/lvol001 /dev/vdc
  Physical volume "/dev/vdc" successfully created
  Volume group "lvm_pool" successfully extended
Phase 1 - find and verify superblock...
Phase 2 - using internal log
        - scan filesystem freespace and inode maps...
        - found root inode chunk
Phase 3 - for each AG...
        - scan (but don't clear) agi unlinked lists...
        - process known inodes and perform inode discovery...
        - agno = 0
        - agno = 1
        - agno = 2
        - agno = 3
        - process newly discovered inodes...
Phase 4 - check for duplicate blocks...
        - setting up duplicate extent list...
        - check for inodes claiming duplicate blocks...
        - agno = 0
        - agno = 1
        - agno = 2
        - agno = 3
No modify flag set, skipping phase 5
Phase 6 - check inode connectivity...
        - traversing filesystem ...
        - traversal finished ...
        - moving disconnected inodes to lost+found ...
Phase 7 - verify link counts...
No modify flag set, skipping filesystem flush and exiting.
  Extending logical volume lvol001 to 1.37 GiB
  Logical volume lvol001 successfully resized
meta-data=/dev/mapper/lvm_pool-lvol001 isize=256    agcount=4,
agsize=57600 blks
         =                       sectsz=512   attr=2, projid32bit=1
         =                       crc=0
data     =                       bsize=4096   blocks=230400, imaxpct=25
         =                       sunit=0      swidth=0 blks
naming   =version 2              bsize=4096   ascii-ci=0 ftype=0
log      =internal               bsize=4096   blocks=853, version=2
         =                       sectsz=512   sunit=0 blks, lazy-count=1
realtime =none                   extsz=4096   blocks=0, rtextents=0
data blocks changed from 230400 to 358400
```

SSM runs a check on the device and then extends the volume by the specified amount. This can be verified with the **`ssm list`** command.

```
~]# ssm list
----------------------------------------------------------------------
Device           Free        Used      Total  Pool      Mount point
----------------------------------------------------------------------
/dev/vda                              15.00 GB            PARTITIONED
/dev/vda1                            500.00 MB            /boot
/dev/vda2    0.00 KB    14.51 GB   14.51 GB  rhel
/dev/vdb     0.00 KB  1020.00 MB    1.00 GB  lvm_pool
/dev/vdc   640.00 MB   380.00 MB    1.00 GB  lvm_pool
----------------------------------------------------------------------
-------------------------------------------------------
Pool      Type  Devices       Free      Used     Total
-------------------------------------------------------
lvm_pool  lvm   2        640.00 MB   1.37 GB   1.99 GB
rhel      lvm   1          0.00 KB  14.51 GB  14.51 GB
-------------------------------------------------------
------------------------------------------------------------------------
----------------------
Volume                  Pool      Volume size  FS      FS size
Free  Type    Mount point
------------------------------------------------------------------------
----------------------
/dev/rhel/root          rhel        13.53 GB  xfs    13.52 GB     9.64 GB
linear  /
/dev/rhel/swap          rhel       1000.00 MB
linear
/dev/lvm_pool/lvol001  lvm_pool      1.37 GB  xfs     1.36 GB     1.36 GB
linear
/dev/vda1                           500.00 MB  xfs   496.67 MB   403.56 MB
part    /boot
------------------------------------------------------------------------
----------------------
```

Note

It is only possible to decrease an LVM volume's size; it is not supported with other volume types. This is done by using a **-** instead of a **+**. For example, to decrease the size of an LVM volume by 50M the command would be:

```
~]# ssm resize -s-50M /dev/lvm_pool/lvol002
  Rounding size to boundary between physical extents: 972.00 MiB
  WARNING: Reducing active logical volume to 972.00 MiB
  THIS MAY DESTROY YOUR DATA (filesystem etc.)
Do you really want to reduce lvol002? [y/n]: y
  Reducing logical volume lvol002 to 972.00 MiB
  Logical volume lvol002 successfully resized
```

Without either the **+** or **-**, the value is taken as absolute.

15.2.6. Snapshot

To take a snapshot of an existing volume, use the **ssm snapshot** command.

Note

This operation will fail if the back end the volume belongs to does not support snapshotting.

To create a snapshot of the **lvol001**, use the following command:

```
~]# ssm snapshot /dev/lvm_pool/lvol001
  Logical volume "snap20150519T130900" created
```

To verify this, use the **ssm list**, and note the extra snapshot section.

```
~]# ssm list
----------------------------------------------------------------
Device        Free        Used      Total  Pool      Mount point
----------------------------------------------------------------
/dev/vda                           15.00 GB            PARTITIONED
/dev/vda1                         500.00 MB            /boot
/dev/vda2  0.00 KB    14.51 GB   14.51 GB  rhel
/dev/vdb   0.00 KB  1020.00 MB    1.00 GB  lvm_pool
/dev/vdc                           1.00 GB
----------------------------------------------------------------
-------------------------------------------------------
Pool      Type  Devices     Free        Used       Total
-------------------------------------------------------
lvm_pool  lvm   1        0.00 KB  1020.00 MB  1020.00 MB
rhel      lvm   1        0.00 KB    14.51 GB    14.51 GB
-------------------------------------------------------
------------------------------------------------------------------------
----------------------
Volume                  Pool      Volume size  FS      FS size
Free  Type    Mount point
------------------------------------------------------------------------
----------------------
/dev/rhel/root          rhel        13.53 GB  xfs    13.52 GB     9.64 GB
linear  /
/dev/rhel/swap          rhel       1000.00 MB
linear
/dev/lvm_pool/lvol001  lvm_pool    900.00 MB  xfs   896.67 MB   896.54 MB
linear
/dev/vda1                           500.00 MB  xfs   496.67 MB   403.56 MB
part    /boot
------------------------------------------------------------------------
----------------------
------------------------------------------------------------------------
----------
Snapshot                          Origin   Pool      Volume size
Size  Type
------------------------------------------------------------------------
----------
```

```
/dev/lvm_pool/snap20150519T130900  lvol001  lvm_pool    120.00 MB  0.00
KB  linear
----------------------------------------------------------------------
----------
```

15.2.7. Remove an item

The **ssm remove** is used to remove an item, either a device, pool, or volume.

Note

If a device is being used by a pool when removed, it will fail. This can be forced using the **-f** argument.

If the volume is mounted when removed, it will fail. Unlike the device, it cannot be forced with the **-f** argument.

To remove the **lvm_pool** and everything within it use the following command:

```
~]# ssm remove lvm_pool
Do you really want to remove volume group "lvm_pool" containing 2
logical volumes? [y/n]: y
Do you really want to remove active logical volume snap20150519T130900?
[y/n]: y
  Logical volume "snap20150519T130900" successfully removed
Do you really want to remove active logical volume lvol001? [y/n]: y
  Logical volume "lvol001" successfully removed
  Volume group "lvm_pool" successfully removed
```

15.3. SSM Resources

Further reading on SSM can be found with the following resources:

- The **man ssm** page provides good descriptions and examples, as well as details on all of the commands and options too specific to be documented here.
- Local documentation for SSM is stored in the **doc/** directory.
- The SSM wiki can be accessed at http://storagemanager.sourceforge.net/index.html.
- The mailing list can be subscribed to from https://lists.sourceforge.net/lists/listinfo/storagemanager-devel and mailing list archives from http://sourceforge.net/mailarchive/forum.php?forum_name=storagemanager-devel. The mailing list is where developers communicate. There is currently no user mailing list so feel free to post questions there as well.

Chapter 16. Disk Quotas

Disk space can be restricted by implementing disk quotas which alert a system administrator before a user consumes too much disk space or a partition becomes full.

Disk quotas can be configured for individual users as well as user groups. This makes it possible to manage the space allocated for user-specific files (such as email) separately from the space allocated to the projects a user works on (assuming the projects are given their own groups).

In addition, quotas can be set not just to control the number of disk blocks consumed but to control the number of inodes (data structures that contain information about files in UNIX file systems). Because inodes are used to contain file-related information, this allows control over the number of files that can be created.

The **quota** RPM must be installed to implement disk quotas.

Note

This chapter is for all file systems, however some file systems have their own quota management tools. Refer to the corresponding description for the applicable file systems.

For XFS file systems, refer to Section 6.3, “XFS Quota Management”.

Btrfs does not have disk quotas so is not covered.

16.1. Configuring Disk Quotas

To implement disk quotas, use the following steps:

1. Enable quotas per file system by modifying the **/etc/fstab** file.
2. Remount the file system(s).
3. Create the quota database files and generate the disk usage table.
4. Assign quota policies.

Each of these steps is discussed in detail in the following sections.

16.1.1. Enabling Quotas

As root, using a text editor, edit the **/etc/fstab** file.

Example 16.1. Edit /etc/fstab

For example, to use the text editor **vim** type the following:

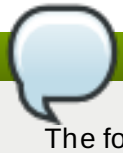
```
# vim /etc/fstab
```

Add the **usrquota** and/or **grpquota** options to the file systems that require quotas:

Example 16.2. Add quotas

```
/dev/VolGroup00/LogVol00 /          ext3    defaults         1 1
LABEL=/boot              /boot      ext3    defaults         1 2
none                     /dev/pts   devpts  gid=5,mode=620   0 0
none                     /dev/shm   tmpfs   defaults         0 0
none                     /proc      proc    defaults         0 0
none                     /sys       sysfs   defaults         0 0
/dev/VolGroup00/LogVol02 /home      ext3    defaults,usrquota,grpquota
1 2
/dev/VolGroup00/LogVol01 swap       swap    defaults         0 0 . . .
```

In this example, the **/home** file system has both user and group quotas enabled.



Note

The following examples assume that a separate **/home** partition was created during the installation of Red Hat Enterprise Linux. The root (**/**) partition can be used for setting quota policies in the **/etc/fstab** file.

16.1.2. Remounting the File Systems

After adding the **usrquota** and/or **grpquota** options, remount each file system whose **fstab** entry has been modified. If the file system is not in use by any process, use one of the following methods:

- Issue the **umount** command followed by the **mount** command to remount the file system. Refer to the **man** page for both **umount** and **mount** for the specific syntax for mounting and unmounting various file system types.
- Issue the **mount -o remount *file-system*** command (where ***file-system*** is the name of the file system) to remount the file system. For example, to remount the **/home** file system, the command to issue is **mount -o remount /home**.

If the file system is currently in use, the easiest method for remounting the file system is to reboot the system.

16.1.3. Creating the Quota Database Files

After each quota-enabled file system is remounted run the **quotacheck** command.

The **quotacheck** command examines quota-enabled file systems and builds a table of the current disk usage per file system. The table is then used to update the operating system's copy of disk usage. In addition, the file system's disk quota files are updated.

Note

The **quotacheck** command has no effect on XFS as the table of disk usage is completed automatically at mount time. Refer to the man page **xfs_quota(8)** for more information.

To create the quota files (**aquota.user** and **aquota.group**) on the file system, use the **-c** option of the **quotacheck** command.

Example 16.3. Create quota files

For example, if user and group quotas are enabled for the **/home** file system, create the files in the **/home** directory:

```
# quotacheck -cug /home
```

The **-c** option specifies that the quota files should be created for each file system with quotas enabled, the **-u** option specifies to check for user quotas, and the **-g** option specifies to check for group quotas.

If neither the **-u** or **-g** options are specified, only the user quota file is created. If only **-g** is specified, only the group quota file is created.

After the files are created, run the following command to generate the table of current disk usage per file system with quotas enabled:

```
# quotacheck -avug
```

The options used are as follows:

a

Check all quota-enabled, locally-mounted file systems

v

Display verbose status information as the quota check proceeds

u

Check user disk quota information

g

Check group disk quota information

After **quotacheck** has finished running, the quota files corresponding to the enabled quotas (user and/or group) are populated with data for each quota-enabled locally-mounted file system such as **/home**.

16.1.4. Assigning Quotas per User

The last step is assigning the disk quotas with the **edquota** command.

To configure the quota for a user, as root in a shell prompt, execute the command:

```
# edquota username
```

Perform this step for each user who needs a quota. For example, if a quota is enabled in **/etc/fstab** for the **/home** partition (**/dev/VolGroup00/LogVol02** in the example below) and the command **edquota testuser** is executed, the following is shown in the editor configured as the default for the system:

```
Disk quotas for user testuser (uid 501):
Filesystem                blocks     soft     hard    inodes   soft
hard
/dev/VolGroup00/LogVol02  440436        0        0     37418      0
0
```

Note

The text editor defined by the **EDITOR** environment variable is used by **edquota**. To change the editor, set the **EDITOR** environment variable in your **~/.bash_profile** file to the full path of the editor of your choice.

The first column is the name of the file system that has a quota enabled for it. The second column shows how many blocks the user is currently using. The next two columns are used to set soft and hard block limits for the user on the file system. The **inodes** column shows how many inodes the user is currently using. The last two columns are used to set the soft and hard inode limits for the user on the file system.

The hard block limit is the absolute maximum amount of disk space that a user or group can use. Once this limit is reached, no further disk space can be used.

The soft block limit defines the maximum amount of disk space that can be used. However, unlike the hard limit, the soft limit can be exceeded for a certain amount of time. That time is known as the *grace period*. The grace period can be expressed in seconds, minutes, hours, days, weeks, or months.

If any of the values are set to 0, that limit is not set. In the text editor, change the desired limits.

Example 16.4. Change desired limits

For example:

```
Disk quotas for user testuser (uid 501):
Filesystem                blocks     soft     hard   inodes   soft
hard
/dev/VolGroup00/LogVol02  440436   500000   550000    37418      0
0
```

To verify that the quota for the user has been set, use the command:

```
# quota username
Disk quotas for user username (uid 501):
   Filesystem  blocks   quota   limit   grace   files   quota   limit
grace
     /dev/sdb    1000*   1000    1000               0       0       0
```

16.1.5. Assigning Quotas per Group

Quotas can also be assigned on a per-group basis. For example, to set a group quota for the **devel** group (the group must exist prior to setting the group quota), use the command:

```
# edquota -g devel
```

This command displays the existing quota for the group in the text editor:

```
Disk quotas for group devel (gid 505):
Filesystem                blocks    soft     hard    inodes    soft
hard
/dev/VolGroup00/LogVol02  440400       0        0     37418       0
0
```

Modify the limits, then save the file.

To verify that the group quota has been set, use the command:

```
# quota -g devel
```

16.1.6. Setting the Grace Period for Soft Limits

If a given quota has soft limits, you can edit the grace period (i.e. the amount of time a soft limit can be exceeded) with the following command:

```
# edquota -t
```

This command works on quotas for inodes or blocks, for either users or groups.

Important

While other **edquota** commands operate on quotas for a particular user or group, the **-t** option operates on every file system with quotas enabled.

16.2. Managing Disk Quotas

If quotas are implemented, they need some maintenance — mostly in the form of watching to see if the quotas are exceeded and making sure the quotas are accurate.

Of course, if users repeatedly exceed their quotas or consistently reach their soft limits, a system administrator has a few choices to make depending on what type of users they are and how much disk space impacts their work. The administrator can either help the user determine how to use less disk space or increase the user's disk quota.

16.2.1. Enabling and Disabling

It is possible to disable quotas without setting them to 0. To turn all user and group quotas off, use the following command:

```
# quotaoff -vaug
```

If neither the **-u** or **-g** options are specified, only the user quotas are disabled. If only **-g** is specified, only group quotas are disabled. The **-v** switch causes verbose status information to display as the command executes.

To enable quotas again, use the **quotaon** command with the same options.

For example, to enable user and group quotas for all file systems, use the following command:

```
# quotaon -vaug
```

To enable quotas for a specific file system, such as **/home**, use the following command:

```
# quotaon -vug /home
```

If neither the **-u** or **-g** options are specified, only the user quotas are enabled. If only **-g** is specified, only group quotas are enabled.

Note

The **quotaon** command is not always needed for XFS because it is performed automatically at mount time. Refer to the man page **quotaon(8)** for more information.

16.2.2. Reporting on Disk Quotas

Creating a disk usage report entails running the **repquota** utility.

Example 16.5. Output of repquota command

For example, the command **repquota /home** produces this output:

```
*** Report for user quotas on device /dev/mapper/VolGroup00-LogVol02
Block grace time: 7days; Inode grace time: 7days
   Block limits   File limits
User  used soft hard grace used soft hard grace
----------------------------------------------------------------------
root      --      36       0       0              4     0     0
kristin   --     540       0       0            125     0     0
testuser  --  440400  500000  550000          37418     0     0
```

To view the disk usage report for all (option **-a**) quota-enabled file systems, use the command:

```
# repquota -a
```

While the report is easy to read, a few points should be explained. The **--** displayed after each user is a quick way to determine whether the block or inode limits have been exceeded. If either soft limit is exceeded, a **+** appears in place of the corresponding **-**; the first **-** represents the block limit, and the second represents the inode limit.

The **grace** columns are normally blank. If a soft limit has been exceeded, the column contains a time specification equal to the amount of time remaining on the grace period. If the grace period has expired, **none** appears in its place.

16.2.3. Keeping Quotas Accurate

When a file system fails to unmount cleanly (due to a system crash, for example), it is necessary to run **quotacheck**. However, **quotacheck** can be run on a regular basis, even if the system has not crashed. Safe methods for periodically running **quotacheck** include:

Ensuring quotacheck runs on next reboot

Note

This method works best for (busy) multiuser systems which are periodically rebooted.

As root, place a shell script into the **/etc/cron.daily/** or **/etc/cron.weekly/** directory—or schedule one using the **crontab -e** command—that contains the **touch /forcequotacheck** command. This creates an empty **forcequotacheck** file in the root directory, which the system init script looks for at boot time. If it is found, the init script runs **quotacheck**. Afterward, the init script removes the **/forcequotacheck** file; thus, scheduling this file to be created periodically with **cron** ensures that **quotacheck** is run during the next reboot.

For more information about **cron**, refer to **man cron**.

Running quotacheck in single user mode

An alternative way to safely run **quotacheck** is to boot the system into single-user mode to prevent the possibility of data corruption in quota files and run the following commands:

```
# quotaoff -vug /file_system
```

```
# quotacheck -vug /file_system
```

```
# quotaon -vug /file_system
```

Running quotacheck on a running system

If necessary, it is possible to run **quotacheck** on a machine during a time when no users are logged in, and thus have no open files on the file system being checked. Run the command **quotacheck -vug *file_system***; this command will fail if **quotacheck** cannot remount the given *file_system* as read-only. Note that, following the check, the file system will be remounted read-write.

Warning

Running **quotacheck** on a live file system mounted read-write is not recommended due to the possibility of quota file corruption.

Refer to **man cron** for more information about configuring **cron**.

16.3. Disk Quota References

For more information on disk quotas, refer to the **man** pages of the following commands:

- **quotacheck**

- **edquota**
- **repquota**
- **quota**
- **quotaon**
- **quotaoff**

Chapter 17. Redundant Array of Independent Disks (RAID)

The basic idea behind RAID is to combine multiple small, inexpensive disk drives into an array to accomplish performance or redundancy goals not attainable with one large and expensive drive. This array of drives appears to the computer as a single logical storage unit or drive.

RAID allows information to be spread across several disks. RAID uses techniques such as *disk striping* (RAID Level 0), *disk mirroring* (RAID Level 1), and *disk striping with parity* (RAID Level 5) to achieve redundancy, lower latency, increased bandwidth, and maximized ability to recover from hard disk crashes.

RAID distributes data across each drive in the array by breaking it down into consistently-sized chunks (commonly 256K or 512k, although other values are acceptable). Each chunk is then written to a hard drive in the RAID array according to the RAID level employed. When the data is read, the process is reversed, giving the illusion that the multiple drives in the array are actually one large drive.

System Administrators and others who manage large amounts of data would benefit from using RAID technology. Primary reasons to deploy RAID include:

- Enhances speed
- Increases storage capacity using a single virtual disk
- Minimizes data loss from disk failure

17.1. RAID Types

There are three possible RAID approaches: Firmware RAID, Hardware RAID and Software RAID.

Firmware RAID

Firmware RAID (also known as ATARAID) is a type of software RAID where the RAID sets can be configured using a firmware-based menu. The firmware used by this type of RAID also hooks into the BIOS, allowing you to boot from its RAID sets. Different vendors use different on-disk metadata formats to mark the RAID set members. The Intel Matrix RAID is a good example of a firmware RAID system.

Hardware RAID

The hardware-based array manages the RAID subsystem independently from the host. It presents a single disk per RAID array to the host.

A Hardware RAID device may be internal or external to the system, with internal devices commonly consisting of a specialized controller card that handles the RAID tasks transparently to the operating system and with external devices commonly connecting to the system via SCSI, Fibre Channel, iSCSI, InfiniBand, or other high speed network interconnect and presenting logical volumes to the system.

RAID controller cards function like a SCSI controller to the operating system, and handle all the actual drive communications. The user plugs the drives into the RAID controller (just like a normal SCSI controller) and then adds them to the RAID controllers configuration. The operating system will not be able to tell the difference.

Software RAID

Software RAID implements the various RAID levels in the kernel disk (block device) code. It offers the cheapest possible solution, as expensive disk controller cards or hot-swap chassis [2] are not required. Software RAID also works with cheaper IDE disks as well as SCSI disks. With today's faster CPUs, Software RAID also generally outperforms Hardware RAID.

The Linux kernel contains a *multi-disk* (MD) driver that allows the RAID solution to be completely hardware independent. The performance of a software-based array depends on the server CPU performance and load.

Here are some of the key features of the Linux software RAID stack:

- Multi-threaded design
- Portability of arrays between Linux machines without reconstruction
- Backgrounded array reconstruction using idle system resources
- Hot-swappable drive support
- Automatic CPU detection to take advantage of certain CPU features such as streaming SIMD support
- Automatic correction of bad sectors on disks in an array
- Regular consistency checks of RAID data to ensure the health of the array
- Proactive monitoring of arrays with email alerts sent to a designated email address on important events
- Write-intent bitmaps which drastically increase the speed of resync events by allowing the kernel to know precisely which portions of a disk need to be resynced instead of having to resync the entire array
- Resync checkpointing so that if you reboot your computer during a resync, at startup the resync will pick up where it left off and not start all over again
- The ability to change parameters of the array after installation. For example, you can grow a 4-disk RAID5 array to a 5-disk RAID5 array when you have a new disk to add. This grow operation is done live and does not require you to reinstall on the new array.

17.2. RAID Levels and Linear Support

RAID supports various configurations, including levels 0, 1, 4, 5, 6, 10, and linear. These RAID types are defined as follows:

Level 0

RAID level 0, often called "striping," is a performance-oriented striped data mapping technique. This means the data being written to the array is broken down into strips and written across the member disks of the array, allowing high I/O performance at low inherent cost but provides no redundancy.

Many RAID level 0 implementations will only stripe the data across the member devices up to the size of the smallest device in the array. This means that if you have multiple devices with slightly different sizes, each device will get treated as though it is the same size as the smallest drive. Therefore, the common storage capacity of a level 0 array is equal to the

capacity of the smallest member disk in a Hardware RAID or the capacity of smallest member partition in a Software RAID multiplied by the number of disks or partitions in the array.

Level 1

RAID level 1, or "mirroring," has been used longer than any other form of RAID. Level 1 provides redundancy by writing identical data to each member disk of the array, leaving a "mirrored" copy on each disk. Mirroring remains popular due to its simplicity and high level of data availability. Level 1 operates with two or more disks, and provides very good data reliability and improves performance for read-intensive applications but at a relatively high cost. [3]

The storage capacity of the level 1 array is equal to the capacity of the smallest mirrored hard disk in a Hardware RAID or the smallest mirrored partition in a Software RAID. Level 1 redundancy is the highest possible among all RAID types, with the array being able to operate with only a single disk present.

Level 4

Level 4 uses parity [4] concentrated on a single disk drive to protect data. Because the dedicated parity disk represents an inherent bottleneck on all write transactions to the RAID array, level 4 is seldom used without accompanying technologies such as write-back caching, or in specific circumstances where the system administrator is intentionally designing the software RAID device with this bottleneck in mind (such as an array that will have little to no write transactions once the array is populated with data). RAID level 4 is so rarely used that it is not available as an option in Anaconda. However, it could be created manually by the user if truly needed.

The storage capacity of Hardware RAID level 4 is equal to the capacity of the smallest member partition multiplied by the number of partitions *minus one*. Performance of a RAID level 4 array will always be asymmetrical, meaning reads will outperform writes. This is because writes consume extra CPU and main memory bandwidth when generating parity, and then also consume extra bus bandwidth when writing the actual data to disks because you are writing not only the data, but also the parity. Reads need only read the data and not the parity unless the array is in a degraded state. As a result, reads generate less traffic to the drives and across the busses of the computer for the same amount of data transfer under normal operating conditions.

Level 5

This is the most common type of RAID. By distributing parity across all of an array's member disk drives, RAID level 5 eliminates the write bottleneck inherent in level 4. The only performance bottleneck is the parity calculation process itself. With modern CPUs and Software RAID, that is usually not a bottleneck at all since modern CPUs can generate parity very fast. However, if you have a sufficiently large number of member devices in a software RAID5 array such that the combined aggregate data transfer speed across all devices is high enough, then this bottleneck can start to come into play.

As with level 4, level 5 has asymmetrical performance, with reads substantially outperforming writes. The storage capacity of RAID level 5 is calculated the same way as with level 4.

Level 6

This is a common level of RAID when data redundancy and preservation, and not performance, are the paramount concerns, but where the space inefficiency of level 1 is not acceptable. Level 6 uses a complex parity scheme to be able to recover from the loss of any

two drives in the array. This complex parity scheme creates a significantly higher CPU burden on software RAID devices and also imposes an increased burden during write transactions. As such, level 6 is considerably more asymmetrical in performance than levels 4 and 5.

The total capacity of a RAID level 6 array is calculated similarly to RAID level 5 and 4, except that you must subtract 2 devices (instead of 1) from the device count for the extra parity storage space.

Level 10

This RAID level attempts to combine the performance advantages of level 0 with the redundancy of level 1. It also helps to alleviate some of the space wasted in level 1 arrays with more than 2 devices. With level 10, it is possible to create a 3-drive array configured to store only 2 copies of each piece of data, which then allows the overall array size to be 1.5 times the size of the smallest devices instead of only equal to the smallest device (like it would be with a 3-device, level 1 array).

The number of options available when creating level 10 arrays (as well as the complexity of selecting the right options for a specific use case) make it impractical to create during installation. It is possible to create one manually using the command line **mdadm** tool. For details on the options and their respective performance trade-offs, refer to **man md**.

Linear RAID

Linear RAID is a simple grouping of drives to create a larger virtual drive. In linear RAID, the chunks are allocated sequentially from one member drive, going to the next drive only when the first is completely filled. This grouping provides no performance benefit, as it is unlikely that any I/O operations will be split between member drives. Linear RAID also offers no redundancy and, in fact, decreases reliability — if any one member drive fails, the entire array cannot be used. The capacity is the total of all member disks.

17.3. Linux RAID Subsystems

RAID in Linux is composed of the following subsystems:

Linux Hardware RAID controller drivers

Hardware RAID controllers have no specific RAID subsystem in Linux. Because they use special RAID chipsets, hardware RAID controllers come with their own drivers; these drivers allow the system to detect the RAID sets as regular disks.

mdraid

The **mdraid** subsystem was designed as a software RAID solution for Linux; it is also the preferred solution for software RAID under Linux. This subsystem uses its own metadata format, generally referred to as native **mdraid** metadata.

mdraid also supports other metadata formats, known as external metadata. Red Hat Enterprise Linux 7 uses **mdraid** with external metadata to access ISW / IMSM (Intel firmware RAID) sets. **mdraid** sets are configured and controlled through the **mdadm** utility.

dmraid

Device-mapper RAID or **dmraid** refers to device-mapper kernel code that offers the mechanism to piece disks together into a RAID set. This same kernel code does not provide any RAID configuration

mechanism.

dmraid is configured entirely in user-space, making it easy to support various on-disk metadata formats. As such, **dmraid** is used on a wide variety of firmware RAID implementations. **dmraid** also supports Intel firmware RAID, although Red Hat Enterprise Linux 7 uses **mdraid** to access Intel firmware RAID sets.

17.4. RAID Support in the Installer

The **Anaconda** installer will automatically detect any hardware and firmware RAID sets on a system, making them available for installation. **Anaconda** also supports software RAID using **mdraid**, and can recognize existing **mdraid** sets.

Anaconda provides utilities for creating RAID sets during installation; however, these utilities only allow partitions (as opposed to entire disks) to be members of new sets. To use an entire disk for a set, simply create a partition on it spanning the entire disk, and use that partition as the RAID set member.

When the root file system uses a RAID set, **Anaconda** will add special kernel command-line options to the bootloader configuration telling the **initrd** which RAID set(s) to activate before searching for the root file system.

For instructions on configuring RAID during installation, refer to the Red Hat Enterprise Linux 7 *Installation Guide*.

17.5. Converting Root Disk to RAID1 after Installation

If you need to convert a non-raided root disk to a RAID1 mirror after installing Red Hat Enterprise Linux 7, see the instructions in the following Red Hat Knowledgebase article: How do I convert my root disk to RAID1 after installation of Red Hat Enterprise Linux 7?

On the PowerPC (PPC) architecture, take the following additional steps:

1. Copy the contents of the PowerPC Reference Platform (PReP) boot partition from **/dev/sda1** to **/dev/sdb1**:

```
# dd if=/dev/sda1 of=/dev/sdb1
```

2. Update the Prep and boot flag on the first partition on both disks:

```
$ parted /dev/sda set 1 prep on
$ parted /dev/sda set 1 boot on

$ parted /dev/sdb set 1 prep on
$ parted /dev/sdb set 1 boot on
```

Note that running the **grub2-install /dev/sda** command does not work on a PowerPC machine and returns an error, but the system boots as expected.

17.6. Configuring RAID Sets

Most RAID sets are configured during creation, typically through the firmware menu or from the installer. In some cases, you may need to create or modify RAID sets after installing the system, preferably without having to reboot the machine and enter the firmware menu to do so.

Some hardware RAID controllers allow you to configure RAID sets on-the-fly or even define completely new sets after adding extra disks. This requires the use of driver-specific utilities, as there is no standard API for this. Refer to your hardware RAID controller's driver documentation for information on this.

mdadm

The **mdadm** command-line tool is used to manage software RAID in Linux, i.e. **mdraid**. For information on the different **mdadm** modes and options, refer to **man mdadm**. The **man** page also contains useful examples for common operations like creating, monitoring, and assembling software RAID arrays.

dmraid

As the name suggests, **dmraid** is used to manage device-mapper RAID sets. The **dmraid** tool finds ATARAID devices using multiple metadata format handlers, each supporting various formats. For a complete list of supported formats, run **dmraid -l**.

As mentioned earlier in Section 17.3, “Linux RAID Subsystems”, the **dmraid** tool cannot configure RAID sets after creation. For more information about using **dmraid**, refer to **man dmraid**.

17.7. Advanced RAID Device Creation

In some cases, you may wish to install the operating system on an array that can't be created after the installation completes. Usually, this means setting up the **/boot** or root file system arrays on a complex RAID device; in such cases, you may need to use array options that are not supported by **Anaconda**. To work around this, perform the following procedure:

Procedure 17.1. Advanced RAID device creation

1. Insert the install disk as you normally would.
2. During the initial boot up, select **Rescue Mode** instead of **Install** or **Upgrade**. When the system fully boots into *Rescue mode*, the user will be presented with a command line terminal.
3. From this terminal, use **parted** to create RAID partitions on the target hard drives. Then, use **mdadm** to manually create raid arrays from those partitions using any and all settings and options available. For more information on how to do these, refer to Chapter 12, *Partitions*, **man parted**, and **man mdadm**.
4. Once the arrays are created, you can optionally create file systems on the arrays as well.
5. Reboot the computer and this time select **Install** or **Upgrade** to install as normal. As **Anaconda** searches the disks in the system, it will find the pre-existing RAID devices.
6. When asked about how to use the disks in the system, select **Custom Layout** and click **Next**. In the device listing, the pre-existing MD RAID devices will be listed.
7. Select a RAID device, click **Edit** and configure its mount point and (optionally) the type of file system it should use (if you did not create one earlier) then click **Done**. **Anaconda** will perform the install to this pre-existing RAID device, preserving the custom options you selected when you created it in *Rescue Mode*.

Note

The limited *Rescue Mode* of the installer does not include **man** pages. Both the **man mdadm** and **man md** contain useful information for creating custom RAID arrays, and may be needed throughout the workaround. As such, it can be helpful to either have access to a machine with these **man** pages present, or to print them out prior to booting into *Rescue Mode* and creating your custom arrays.

[2] A hot-swap chassis allows you to remove a hard drive without having to power-down your system.

[3] RAID level 1 comes at a high cost because you write the same information to all of the disks in the array, provides data reliability, but in a much less space-efficient manner than parity based RAID levels such as level 5. However, this space inefficiency comes with a performance benefit: parity-based RAID levels consume considerably more CPU power in order to generate the parity while RAID level 1 simply writes the same data more than once to the multiple RAID members with very little CPU overhead. As such, RAID level 1 can outperform the parity-based RAID levels on machines where software RAID is employed and CPU resources on the machine are consistently taxed with operations other than RAID activities.

[4] Parity information is calculated based on the contents of the rest of the member disks in the array. This information can then be used to reconstruct data when one disk in the array fails. The reconstructed data can then be used to satisfy I/O requests to the failed disk before it is replaced and to repopulate the failed disk after it has been replaced.

Chapter 18. Using the `mount` Command

On Linux, UNIX, and similar operating systems, file systems on different partitions and removable devices (CDs, DVDs, or USB flash drives for example) can be attached to a certain point (the *mount point*) in the directory tree, and then detached again. To attach or detach a file system, use the **mount** or **umount** command respectively. This chapter describes the basic use of these commands, as well as some advanced topics, such as moving a mount point or creating shared subtrees.

18.1. Listing Currently Mounted File Systems

To display all currently attached file systems, run the **mount** command with no additional arguments:

```
mount
```

This command displays the list of known mount points. Each line provides important information about the device name, the file system type, the directory in which it is mounted, and relevant mount options in the following form:

device on *directory* type *type* (*options*)

The **findmnt** utility, which allows users to list mounted file systems in a tree-like form, is also available from Red Hat Enterprise Linux 6.1. To display all currently attached file systems, run the **findmnt** command with no additional arguments:

```
findmnt
```

18.1.1. Specifying the File System Type

By default, the output of the **mount** command includes various virtual file systems such as **sysfs** and **tmpfs**. To display only the devices with a certain file system type, supply the **-t** option on the command line:

```
mount -t type
```

Similarly, to display only the devices with a certain file system type by using the **findmnt** command, type:

```
findmnt -t type
```

For a list of common file system types, refer to Table 18.1, “Common File System Types”. For an example usage, see Example 18.1, “Listing Currently Mounted **ext4** File Systems”.

Example 18.1. Listing Currently Mounted ext4 File Systems

Usually, both **/** and **/boot** partitions are formatted to use **ext4**. To display only the mount points that use this file system, type the following at a shell prompt:

```
~]$ mount -t ext4
/dev/sda2 on / type ext4 (rw)
/dev/sda1 on /boot type ext4 (rw)
```

To list such mount points using the **findmnt** command, type:

```
~]$ findmnt -t ext4
TARGET SOURCE    FSTYPE OPTIONS
/      /dev/sda2 ext4   rw,realtime,seclabel,barrier=1,data=ordered
/boot  /dev/sda1 ext4   rw,realtime,seclabel,barrier=1,data=ordered
```

18.2. Mounting a File System

To attach a certain file system, use the **mount** command in the following form:

```
mount [option…] device directory
```

The *device* can be identified by a full path to a *block device* (for example, “/dev/sda3”), a *universally unique identifier* (UUID; for example, “UUID=34795a28-ca6d-4fd8-a347-73671d0c19cb”), or a *volume label* (for example, “LABEL=home”). Note that while a file system is mounted, the original content of the *directory* is not accessible.

Important

Linux does not prevent a user from mounting a file system to a directory with a file system already attached to it. To determine whether a particular directory serves as a mount point, run the **findmnt** utility with the directory as its argument and verify the exit code:

```
findmnt directory; echo $?
```

If no file system is attached to the directory, the above command returns **1**.

When the **mount** command is run without all required information (that is, without the device name, the target directory, or the file system type), it reads the content of the **/etc/fstab** configuration file to see if the given file system is listed. This file contains a list of device names and the directories in which the selected file systems should be mounted, as well as the file system type and mount options. Because of this, when mounting a file system that is specified in this file, you can use one of the following variants of the command:

```
mount [option…] directory
mount [option…] device
```

Note that permissions are required to mount the file systems unless the command is run as **root** (see Section 18.2.2, “Specifying the Mount Options”).

Note

To determine the UUID and—if the device uses it—the label of a particular device, use the **blkid** command in the following form:

```
blkid device
```

For example, to display information about **/dev/sda3**, type:

```
~]# blkid /dev/sda3
/dev/sda3: LABEL="home" UUID="34795a28-ca6d-4fd8-a347-73671d0c19cb"
TYPE="ext3"
```

18.2.1. Specifying the File System Type

In most cases, **mount** detects the file system automatically. However, there are certain file systems, such as **NFS** (Network File System) or **CIFS** (Common Internet File System), that are not recognized, and need to be specified manually. To specify the file system type, use the **mount** command in the following form:

```
mount -t type device directory
```

Table 18.1, “Common File System Types” provides a list of common file system types that can be used with the **mount** command. For a complete list of all available file system types, consult the relevant manual page as referred to in Section 18.4.1, “Manual Page Documentation”.

Table 18.1. Common File System Types

Type	Description
ext2	The **ext2** file system.
ext3	The **ext3** file system.
ext4	The **ext4** file system.
btrfs	The **btrfs** file system.
xfs	The **xfs** file system.
iso9660	The **ISO 9660** file system. It is commonly used by optical media, typically CDs.
jfs	The **JFS** file system created by IBM.
nfs	The **NFS** file system. It is commonly used to access files over the network.
nfs4	The **NFSv4** file system. It is commonly used to access files over the network.
ntfs	The **NTFS** file system. It is commonly used on machines that are running the Windows operating system.
udf	The **UDF** file system. It is commonly used by optical media, typically DVDs.
vfat	The **FAT** file system. It is commonly used on machines that are running the Windows operating system, and on certain digital media such as USB flash drives or floppy disks.

See Example 18.2, “Mounting a USB Flash Drive” for an example usage.

Example 18.2. Mounting a USB Flash Drive

Older USB flash drives often use the FAT file system. Assuming that such drive uses the **/dev/sdc1** device and that the **/media/flashdisk/** directory exists, mount it to this directory by typing the following at a shell prompt as **root**:

```
~]# mount -t vfat /dev/sdc1 /media/flashdisk
```

18.2.2. Specifying the Mount Options

To specify additional mount options, use the command in the following form:

```
mount -o options device directory
```

When supplying multiple options, do not insert a space after a comma, or **mount** will incorrectly interpret the values following spaces as additional parameters.

Table 18.2, "Common Mount Options" provides a list of common mount options. For a complete list of all available options, consult the relevant manual page as referred to in Section 18.4.1, "Manual Page Documentation".

Table 18.2. Common Mount Options

Option	Description
async	Allows the asynchronous input/output operations on the file system.
auto	Allows the file system to be mounted automatically using the **mount -a** command.
defaults	Provides an alias for **async,auto,dev,exec,nouser,rw,suid**.
exec	Allows the execution of binary files on the particular file system.
loop	Mounts an image as a loop device.
noauto	Default behavior disallows the automatic mount of the file system using the **mount -a** command.
noexec	Disallows the execution of binary files on the particular file system.
nouser	Disallows an ordinary user (that is, other than **root**) to mount and unmount the file system.
remount	Remounts the file system in case it is already mounted.
ro	Mounts the file system for reading only.
rw	Mounts the file system for both reading and writing.
user	Allows an ordinary user (that is, other than **root**) to mount and unmount the file system.

See Example 18.3, "Mounting an ISO Image" for an example usage.

Example 18.3. Mounting an ISO Image

An ISO image (or a disk image in general) can be mounted by using the loop device. Assuming that the ISO image of the Fedora 14 installation disc is present in the current working directory and that the **/media/cdrom/** directory exists, mount the image to this directory by running the following command as **root**:

```
~]# mount -o ro,loop Fedora-14-x86_64-Live-Desktop.iso /media/cdrom
```

Note that ISO 9660 is by design a read-only file system.

18.2.3. Sharing Mounts

Occasionally, certain system administration tasks require access to the same file system from more than one place in the directory tree (for example, when preparing a chroot environment). This is possible, and Linux allows you to mount the same file system to as many directories as necessary. Additionally, the **mount** command implements the **--bind** option that provides a means for duplicating certain mounts. Its usage is as follows:

```
mount --bind old_directory new_directory
```

Although this command allows a user to access the file system from both places, it does not apply on the file systems that are mounted within the original directory. To include these mounts as well, type:

```
mount --rbind old_directory new_directory
```

Additionally, to provide as much flexibility as possible, Red Hat Enterprise Linux 7 implements the functionality known as *shared subtrees*. This feature allows the use of the following four mount types:

Shared Mount

A shared mount allows the creation of an exact replica of a given mount point. When a mount point is marked as a shared mount, any mount within the original mount point is reflected in it, and vice versa. To change the type of a mount point to a shared mount, type the following at a shell prompt:

```
mount --make-shared mount_point
```

Alternatively, to change the mount type for the selected mount point and all mount points under it, type:

```
mount --make-rshared mount_point
```

See Example 18.4, “Creating a Shared Mount Point” for an example usage.

Example 18.4. Creating a Shared Mount Point

There are two places where other file systems are commonly mounted: the **/media** directory for removable media, and the **/mnt** directory for temporarily mounted file systems. By using a shared mount, you can make these two directories share the same content. To do so, as **root**, mark the **/media** directory as “shared”:

```
~]# mount --bind /media /media
~]# mount --make-shared /media
```

Then create its duplicate in **/mnt** by using the following command:

```
~]# mount --bind /media /mnt
```

It is now possible to verify that a mount within **/media** also appears in **/mnt**. For example, if the CD-ROM drive contains non-empty media and the **/media/cdrom/** directory exists, run the following commands:

```
~]# mount /dev/cdrom /media/cdrom
~]# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
~]# ls /mnt/cdrom
EFI  GPL  isolinux  LiveOS
```

Similarly, it is possible to verify that any file system mounted in the **/mnt** directory is reflected in **/media**. For instance, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, type:

```
~]# mount /dev/sdc1 /mnt/flashdisk
~]# ls /media/flashdisk
en-US  publican.cfg
~]# ls /mnt/flashdisk
en-US  publican.cfg
```

Slave Mount

A slave mount allows the creation of a limited duplicate of a given mount point. When a mount point is marked as a slave mount, any mount within the original mount point is reflected in it, but no mount within a slave mount is reflected in its original. To change the type of a mount point to a slave mount, type the following at a shell prompt:

```
mount --make-slave mount_point
```

Alternatively, it is possible to change the mount type for the selected mount point and all mount points under it by typing:

```
mount --make-rslave mount_point
```

See Example 18.5, “Creating a Slave Mount Point” for an example usage.

Example 18.5. Creating a Slave Mount Point

This example shows how to get the content of the **/media** directory to appear in **/mnt** as well, but without any mounts in the **/mnt** directory to be reflected in **/media**. As **root**, first mark the **/media** directory as “shared”:

```
~]# mount --bind /media /media
~]# mount --make-shared /media
```

Then create its duplicate in **/mnt**, but mark it as “slave”:

```
~]# mount --bind /media /mnt
~]# mount --make-slave /mnt
```

Now verify that a mount within **/media** also appears in **/mnt**. For example, if the CD-ROM drive contains non-empty media and the **/media/cdrom/** directory exists, run the following commands:

```
~]# mount /dev/cdrom /media/cdrom
~]# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
~]# ls /mnt/cdrom
EFI  GPL  isolinux  LiveOS
```

Also verify that file systems mounted in the **/mnt** directory are not reflected in **/media**. For instance, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, type:

```
~]# mount /dev/sdc1 /mnt/flashdisk
~]# ls /media/flashdisk
~]# ls /mnt/flashdisk
en-US  publican.cfg
```

Private Mount

A private mount is the default type of mount, and unlike a shared or slave mount, it does not receive or forward any propagation events. To explicitly mark a mount point as a private mount, type the following at a shell prompt:

```
mount --make-private mount_point
```

Alternatively, it is possible to change the mount type for the selected mount point and all mount points under it:

```
mount --make-rprivate mount_point
```

See Example 18.6, “Creating a Private Mount Point” for an example usage.

Example 18.6. Creating a Private Mount Point

Taking into account the scenario in Example 18.4, “Creating a Shared Mount Point”, assume that a shared mount point has been previously created by using the following commands as **root**:

```
~]# mount --bind /media /media
~]# mount --make-shared /media
~]# mount --bind /media /mnt
```

To mark the **/mnt** directory as “private”, type:

```
~]# mount --make-private /mnt
```

It is now possible to verify that none of the mounts within **/media** appears in **/mnt**. For example, if the CD-ROM drives contains non-empty media and the **/media/cdrom/** directory exists, run the following commands:

```
~]# mount /dev/cdrom /media/cdrom
~]# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
~]# ls /mnt/cdrom
~]#
```

It is also possible to verify that file systems mounted in the **/mnt** directory are not reflected in **/media**. For instance, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, type:

```
~]# mount /dev/sdc1 /mnt/flashdisk
~]# ls /media/flashdisk
~]# ls /mnt/flashdisk
en-US  publican.cfg
```

Unbindable Mount

In order to prevent a given mount point from being duplicated whatsoever, an unbindable mount is used. To change the type of a mount point to an unbindable mount, type the following at a shell prompt:

```
mount --make-unbindable mount_point
```

Alternatively, it is possible to change the mount type for the selected mount point and all mount points under it:

```
mount --make-runbindable mount_point
```

See Example 18.7, “Creating an Unbindable Mount Point” for an example usage.

Example 18.7. Creating an Unbindable Mount Point

To prevent the **/media** directory from being shared, as **root**, type the following at a shell prompt:

```
~]# mount --bind /media /media
~]# mount --make-unbindable /media
```

This way, any subsequent attempt to make a duplicate of this mount will fail with an error:

```
~]# mount --bind /media /mnt
mount: wrong fs type, bad option, bad superblock on /media,
missing codepage or helper program, or other error
In some cases useful info is found in syslog - try
dmesg | tail  or so
```

18.2.4. Moving a Mount Point

To change the directory in which a file system is mounted, use the following command:

```
mount --move old_directory new_directory
```

See Example 18.8, “Moving an Existing NFS Mount Point” for an example usage.

Example 18.8. Moving an Existing NFS Mount Point

An NFS storage contains user directories and is already mounted in **/mnt/userdirs/**. As **root**, move this mount point to **/home** by using the following command:

```
~]# mount --move /mnt/userdirs /home
```

To verify the mount point has been moved, list the content of both directories:

```
~]# ls /mnt/userdirs
~]# ls /home
jill  joe
```

18.3. Unmounting a File System

To detach a previously mounted file system, use either of the following variants of the **umount** command:

```
umount directory
umount device
```

Note that unless this is performed while logged in as **root**, the correct permissions must be available to unmount the file system (see Section 18.2.2, “Specifying the Mount Options”). See Example 18.9, “Unmounting a CD” for an example usage.

Important

When a file system is in use (for example, when a process is reading a file on this file system, or when it is used by the kernel), running the **umount** command will fail with an error. To determine which processes are accessing the file system, use the **fuser** command in the following form:

```
fuser -m directory
```

For example, to list the processes that are accessing a file system mounted to the **/media/cdrom/** directory, type:

```
~]$ fuser -m /media/cdrom
/media/cdrom:         1793  2013  2022  2435 10532c 10672c
```

Example 18.9. Unmounting a CD

To unmount a CD that was previously mounted to the **/media/cdrom/** directory, type the following at a shell prompt:

```
~]$ umount /media/cdrom
```

18.4. mount Command References

The following resources provide an in-depth documentation on the subject.

18.4.1. Manual Page Documentation

- **man 8 mount** — The manual page for the **mount** command that provides a full documentation on its usage.
- **man 8 umount** — The manual page for the **umount** command that provides a full documentation on its usage.
- **man 8 findmnt** — The manual page for the **findmnt** command that provides a full documentation on its usage.
- **man 5 fstab** — The manual page providing a thorough description of the **/etc/fstab** file format.

18.4.2. Useful Websites

- *Shared subtrees* — An LWN article covering the concept of shared subtrees.

Chapter 19. The `volume_key` Function

The volume_key function provides two tools, libvolume_key and **`volume_key`**. libvolume_key is a library for manipulating storage volume encryption keys and storing them separately from volumes. **`volume_key`** is an associated command line tool used to extract keys and passphrases in order to restore access to an encrypted hard drive.

This is useful for when the primary user forgets their keys and passwords, after an employee leaves abruptly, or in order to extract data after a hardware or software failure corrupts the header of the encrypted volume. In a corporate setting, the IT help desk can use **`volume_key`** to back up the encryption keys before handing over the computer to the end user.

Currently, **`volume_key`** only supports the LUKS volume encryption format.

Note

`volume_key` is not included in a standard install of Red Hat Enterprise Linux 7 server. For information on installing it, refer to http://fedoraproject.org/wiki/Disk_encryption_key_escrow_use_cases.

19.1. `volume_key` Commands

The format for **`volume_key`** is:

```
volume_key [OPTION]... OPERAND
```

The operands and mode of operation for **`volume_key`** are determined by specifying one of the following options:

`--save`

This command expects the operand *volume* [*packet*]. If a *packet* is provided then **`volume_key`** will extract the keys and passphrases from it. If *packet* is not provided, then **`volume_key`** will extract the keys and passphrases from the *volume*, prompting the user where necessary. These keys and passphrases will then be stored in one or more output packets.

`--restore`

This command expects the operands *volume packet*. It then opens the *volume* and uses the keys and passphrases in the *packet* to make the *volume* accessible again, prompting the user where necessary, such as allowing the user to enter a new passphrase, for example.

`--setup-volume`

This command expects the operands *volume packet name*. It then opens the *volume* and uses the keys and passphrases in the *packet* to set up the *volume* for use of the decrypted data as *name*.

Name is the name of a dm-crypt volume. This operation makes the decrypted volume available as **`/dev/mapper/name`**.

This operation does not permanently alter the *volume* by adding a new passphrase, for example. The user can access and modify the decrypted volume, modifying *volume* in the

process.

--reencrypt, --secrets, and --dump

These three commands perform similar functions with varying output methods. They each require the operand *packet*, and each opens the *packet*, decrypting it where necessary. **--reencrypt** then stores the information in one or more new output packets. **--secrets** outputs the keys and passphrases contained in the *packet*. **--dump** outputs the content of the *packet*, though the keys and passphrases are not output by default. This can be changed by appending **--with-secrets** to the command. It is also possible to only dump the unencrypted parts of the packet, if any, by using the **--unencrypted** command. This does not require any passphrase or private key access.

Each of these can be appended with the following options:

-o, --output *packet*

This command writes the default key or passphrase to the *packet*. The default key or passphrase depends on the volume format. Ensure it is one that is unlikely to expire, and will allow **--restore** to restore access to the volume.

--output-format *format*

This command uses the specified *format* for all output packets. Currently, *format* can be one of the following:

- **asymmetric**: uses CMS to encrypt the whole packet, and requires a certificate
- **asymmetric_wrap_secret_only**: wraps only the secret, or keys and passphrases, and requires a certificate
- **passphrase**: uses GPG to encrypt the whole packet, and requires a passphrase

--create-random-passphrase *packet*

This command generates a random alphanumeric passphrase, adds it to the *volume* (without affecting other passphrases), and then stores this random passphrase into the *packet*.

19.2. Using volume_key as an individual user

As an individual user, **volume_key** can be used to save encryption keys by using the following procedure.

Note

For all examples in this file, ***/path/to/volume*** is a LUKS device, not the plaintext device contained within. **blkid -s *type* /path/to/volume** should report ***type*="crypto_LUKS"**.

Procedure 19.1. Using volume_key stand-alone

1. Run:

```
volume_key --save /path/to/volume -o escrow-packet
```

A prompt will then appear requiring an escrow packet passphrase to protect the key.

2. Save the generated **escrow-packet** file, ensuring that the passphrase is not forgotten.

If the volume passphrase is forgotten, use the saved escrow packet to restore access to the data.

Procedure 19.2. Restore access to data with escrow packet

1. Boot the system in an environment where **volume_key** can be run and the escrow packet is available (a rescue mode, for example).
2. Run:

```
volume_key --restore /path/to/volume escrow-packet
```

A prompt will appear for the escrow packet passphrase that was used when creating the escrow packet, and for the new passphrase for the volume.

3. Mount the volume using the chosen passphrase.

To free up the passphrase slot in the LUKS header of the encrypted volume, remove the old, forgotten passphrase by using the command **cryptsetup luksKillSlot**.

19.3. Using volume_key in a larger organization

In a larger organization, using a single password known by every system administrator and keeping track of a separate password for each system is impractical and a security risk. To counter this, **volume_key** can use asymmetric cryptography to minimize the number of people who know the password required to access encrypted data on any computer.

This section will cover the procedures required for preparation before saving encryption keys, how to save encryption keys, restoring access to a volume, and setting up emergency passphrases.

19.3.1. Preparation for saving encryption keys

In order to begin saving encryption keys, some preparation is required.

Procedure 19.3. Preparation

1. Create an X509 certificate/private pair.
2. Designate trusted users who are trusted not to compromise the private key. These users will be able to decrypt the escrow packets.
3. Choose which systems will be used to decrypt the escrow packets. On these systems, set up an NSS database that contains the private key.

   If the private key was not created in an NSS database, follow these steps:

   A. Store the certificate and private key in an **PKCS#12** file.

   B. Run:

```
certutil -d /the/nss/directory -N
```

At this point it is possible to choose an NSS database password. Each NSS database can have a different password so the designated users do not need to share a single password if a separate NSS database is used by each user.

C. Run:

```
pk12util -d /the/nss/directory -i the-pkcs12-file
```

4. Distribute the certificate to anyone installing systems or saving keys on existing systems.

5. For saved private keys, prepare storage that allows them to be looked up by machine and volume. For example, this can be a simple directory with one subdirectory per machine, or a database used for other system management tasks as well.

19.3.2. Saving encryption keys

After completing the required preparation (see Section 19.3.1, “Preparation for saving encryption keys”) it is now possible to save the encryption keys using the following procedure.

Note

For all examples in this file, **/path/to/volume** is a LUKS device, not the plaintext device contained within; **blkid -s *type* */path/to/volume*** should report ***type*="crypto_LUKS"**.

Procedure 19.4. Saving encryption keys

1. Run:

```
volume_key --save /path/to/volume -c /path/to/cert escrow-packet
```

2. Save the generated **escrow-packet** file in the prepared storage, associating it with the system and the volume.

These steps can be performed manually, or scripted as part of system installation.

19.3.3. Restoring access to a volume

After the encryption keys have been saved (see Section 19.3.1, “Preparation for saving encryption keys” and Section 19.3.2, “Saving encryption keys”), access can be restored to a driver where needed.

Procedure 19.5. Restoring access to a volume

1. Get the escrow packet for the volume from the packet storage and send it to one of the designated users for decryption.

2. The designated user runs:

```
volume_key --reencrypt -d /the/nss/directory escrow-packet-in -o
escrow-packet-out
```

After providing the NSS database password, the designated user chooses a passphrase for encrypting **escrow-packet-out**. This passphrase can be different every time and only protects the encryption keys while they are moved from the designated user to the target system.

3. Obtain the **escrow-packet-out** file and the passphrase from the designated user.
4. Boot the target system in an environment that can run **volume_key** and have the **escrow-packet-out** file available, such as in a rescue mode.
5. Run:

```
volume_key --restore /path/to/volume escrow-packet-out
```

A prompt will appear for the packet passphrase chosen by the designated user, and for a new passphrase for the volume.

6. Mount the volume using the chosen volume passphrase.

It is possible to remove the old passphrase that was forgotten by using **cryptsetup luksKillSlot**, for example, to free up the passphrase slot in the LUKS header of the encrypted volume. This is done with the command **cryptsetup luksKillSlot *device key-slot***. For more information and examples see **cryptsetup --help**.

19.3.4. Setting up emergency passphrases

In some circumstances (such as traveling for business) it is impractical for system administrators to work directly with the affected systems, but users still need access to their data. In this case, **volume_key** can work with passphrases as well as encryption keys.

During the system installation, run:

```
volume_key --save /path/to/volume -c /path/to/ert --create-random-passphrase passphrase-packet
```

This generates a random passphrase, adds it to the specified volume, and stores it to ***passphrase-packet***. It is also possible to combine the **--create-random-passphrase** and **-o** options to generate both packets at the same time.

If a user forgets the password, the designated user runs:

```
volume_key --secrets -d /your/nss/directory passphrase-packet
```

This shows the random passphrase. Give this passphrase to the end user.

19.4. volume_key References

More information on **volume_key** can be found:

- in the readme file located at **/usr/share/doc/volume_key-*/README**
- on **volume_key**'s manpage using **man volume_key**
- online at http://fedoraproject.org/wiki/Disk_encryption_key_escrow_use_cases

Chapter 20. Access Control Lists

Files and directories have permission sets for the owner of the file, the group associated with the file, and all other users for the system. However, these permission sets have limitations. For example, different permissions cannot be configured for different users. Thus, *Access Control Lists* (ACLs) were implemented.

The Red Hat Enterprise Linux kernel provides ACL support for the ext3 file system and NFS-exported file systems. ACLs are also recognized on ext3 file systems accessed via Samba.

Along with support in the kernel, the **acl** package is required to implement ACLs. It contains the utilities used to add, modify, remove, and retrieve ACL information.

The **cp** and **mv** commands copy or move any ACLs associated with files and directories.

20.1. Mounting File Systems

Before using ACLs for a file or directory, the partition for the file or directory must be mounted with ACL support. If it is a local ext3 file system, it can mounted with the following command:

mount -t ext3 -o acl *device-name partition*

For example:

mount -t ext3 -o acl /dev/VolGroup00/LogVol02 /work

Alternatively, if the partition is listed in the **/etc/fstab** file, the entry for the partition can include the **acl** option:

```
LABEL=/work      /work       ext3    acl         1 2
```

If an ext3 file system is accessed via Samba and ACLs have been enabled for it, the ACLs are recognized because Samba has been compiled with the **--with-acl-support** option. No special flags are required when accessing or mounting a Samba share.

20.1.1. NFS

By default, if the file system being exported by an NFS server supports ACLs and the NFS client can read ACLs, ACLs are utilized by the client system.

To disable ACLs on NFS shares when configuring the server, include the **no_acl** option in the **/etc/exports** file. To disable ACLs on an NFS share when mounting it on a client, mount it with the **no_acl** option via the command line or the **/etc/fstab** file.

20.2. Setting Access ACLs

There are two types of ACLs: *access ACLs* and *default ACLs*. An access ACL is the access control list for a specific file or directory. A default ACL can only be associated with a directory; if a file within the directory does not have an access ACL, it uses the rules of the default ACL for the directory. Default ACLs are optional.

ACLs can be configured:

1. Per user

2. Per group
3. Via the effective rights mask
4. For users not in the user group for the file

The **setfacl** utility sets ACLs for files and directories. Use the **-m** option to add or modify the ACL of a file or directory:

```
# setfacl -m rules files
```

Rules (*rules*) must be specified in the following formats. Multiple rules can be specified in the same command if they are separated by commas.

u:*uid*:*perms*

Sets the access ACL for a user. The user name or UID may be specified. The user may be any valid user on the system.

g:*gid*:*perms*

Sets the access ACL for a group. The group name or GID may be specified. The group may be any valid group on the system.

m:*perms*

Sets the effective rights mask. The mask is the union of all permissions of the owning group and all of the user and group entries.

o:*perms*

Sets the access ACL for users other than the ones in the group for the file.

Permissions (*perms*) must be a combination of the characters **r**, **w**, and **x** for read, write, and execute.

If a file or directory already has an ACL, and the **setfacl** command is used, the additional rules are added to the existing ACL or the existing rule is modified.

Example 20.1. Give read and write permissions

For example, to give read and write permissions to user andrius:

```
# setfacl -m u:andrius:rw /project/somefile
```

To remove all the permissions for a user, group, or others, use the **-x** option and do not specify any permissions:

```
# setfacl -x rules files
```

Example 20.2. Remove all permissions

For example, to remove all permissions from the user with UID 500:

```
# setfacl -x u:500 /project/somefile
```

20.3. Setting Default ACLs

To set a default ACL, add **d:** before the rule and specify a directory instead of a file name.

Example 20.3. Setting default ACLs

For example, to set the default ACL for the **/share/** directory to read and execute for users not in the user group (an access ACL for an individual file can override it):

```
# setfacl -m d:o:rx /share
```

20.4. Retrieving ACLs

To determine the existing ACLs for a file or directory, use the **getfacl** command. In the example below, the **getfacl** is used to determine the existing ACLs for a file.

Example 20.4. Retrieving ACLs

```
# getfacl home/john/picture.png
```

The above command returns the following output:

```
# file: home/john/picture.png
# owner: john
# group: john
user::rw-
group::r--
other::r--
```

If a directory with a default ACL is specified, the default ACL is also displayed as illustrated below. For example, **getfacl home/sales/** will display similar output:

```
# file: home/sales/
# owner: john
# group: john
user::rw-
user:barryg:r--
group::r--
mask::r--
other::r--
default:user::rwx
default:user:john:rwx
default:group::r-x
default:mask::rwx
default:other::r-x
```

20.5. Archiving File Systems With ACLs

By default, the **dump** command now preserves ACLs during a backup operation. When archiving a file or file system with **tar**, use the **--acls** option to preserve ACLs. Similarly, when using **cp** to copy files with ACLs, include the **--preserve=mode** option to ensure that ACLs are copied across too. In addition, the **-a** option (equivalent to **-dR --preserve=all**) of **cp** also preserves ACLs during a backup along with other information such as timestamps, SELinux contexts, and the like. For more information about **dump**, **tar**, or **cp**, refer to their respective **man** pages.

The **star** utility is similar to the **tar** utility in that it can be used to generate archives of files; however, some of its options are different. Refer to Table 20.1, “Command Line Options for **star**” for a listing of more commonly used options. For all available options, refer to **man star**. The **star** package is required to use this utility.

Table 20.1. Command Line Options for star

Option	Description
-c	Creates an archive file.
-n	Do not extract the files; use in conjunction with **-x** to show what extracting the files does.
-r	Replaces files in the archive. The files are written to the end of the archive file, replacing any files with the same path and file name.
-t	Displays the contents of the archive file.
-u	Updates the archive file. The files are written to the end of the archive if they do not exist in the archive, or if the files are newer than the files of the same name in the archive. This option only works if the archive is a file or an unblocked tape that may backspace.
-x	Extracts the files from the archive. If used with **-U** and a file in the archive is older than the corresponding file on the file system, the file is not extracted.
-help	Displays the most important options.
-xhelp	Displays the least important options.
-/	Do not strip leading slashes from file names when extracting the files from an archive. By default, they are stripped when files are extracted.
-acl	When creating or extracting, archives or restores any ACLs associated with the files and directories.

20.6. Compatibility with Older Systems

If an ACL has been set on any file on a given file system, that file system has the **ext_attr** attribute. This attribute can be seen using the following command:

```
# tune2fs -l filesystem-device
```

A file system that has acquired the **ext_attr** attribute can be mounted with older kernels, but those kernels do not enforce any ACLs which have been set.

Versions of the **e2fsck** utility included in version 1.22 and higher of the **e2fsprogs** package (including the versions in Red Hat Enterprise Linux 2.1 and 4) can check a file system with the **ext_attr** attribute. Older versions refuse to check it.

20.7. ACL References

Refer to the following man pages for more information.

- **man acl** — Description of ACLs
- **man getfacl** — Discusses how to get file access control lists
- **man setfacl** — Explains how to set file access control lists
- **man star** — Explains more about the **star** utility and its many options

Chapter 21. Solid-State Disk Deployment Guidelines

Solid-state disks (SSD) are storage devices that use NAND flash chips to persistently store data. This sets them apart from previous generations of disks, which store data in rotating, magnetic platters. In an SSD, the access time for data across the full Logical Block Address (LBA) range is constant; whereas with older disks that use rotating media, access patterns that span large address ranges incur seek costs. As such, SSD devices have better latency and throughput.

Performance degrades as the number of used blocks approaches the disk capacity. The degree of performance impact varies greatly by vendor. However, all devices experience some degradation.

To address the degradation issue, the host system (for example, the Linux kernel) may use discard requests to inform the storage that a given range of blocks is no longer in use. An SSD can use this information to free up space internally, using the free blocks for wear-leveling. Discards will only be issued if the storage advertises support in terms of its storage protocol (be it ATA or SCSI). Discard requests are issued to the storage using the negotiated discard command specific to the storage protocol (**TRIM** command for ATA, and **WRITE SAME** with **UNMAP** set, or **UNMAP** command for SCSI).

Enabling **discard** support is most useful when the following two points are true:

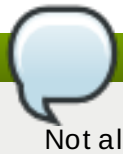
- Free space is still available on the file system.
- Most logical blocks on the underlying storage device have already been written to.

For more information about **TRIM**, refer to its *Data Set Management T13 Specifications* from the following link:

http://t13.org/Documents/UploadedDocuments/docs2008/e07154r6-Data_Set_Management_Proposal_for_ATA-ACS2.doc

For more information about **UNMAP**, refer to section 4.7.3.4 of the *SCSI Block Commands 3 T10 Specification* from the following link:

http://www.t10.org/cgi-bin/ac.pl?t=f&f=sbc3r26.pdf



Note

Not all solid-state devices in the market have **discard** support. To determine if your solid-state device has **discard** support check for **/sys/block/sda/queue/discard_granularity**.

21.1. Deployment Considerations

Because of the internal layout and operation of SSDs, it is best to partition devices on an internal *erase block boundary*. Partitioning utilities in Red Hat Enterprise Linux 7 chooses sane defaults if the SSD exports topology information.

However, if the device *does not* export topology information, Red Hat recommends that the first partition be created at a 1MB boundary.

The Logical Volume Manager (LVM), the device-mapper (DM) targets, and MD (software raid) targets that LVM uses support discards. The only DM targets that do not support discards are dm-snapshot, dm-crypt, and dm-raid45. Discard support for the dm-mirror was added in Red Hat Enterprise Linux 6.1 and as of 7.0 MD supports discards.

Red Hat also warns that software RAID levels 1, 4, 5, and 6 are not recommended for use on SSDs. During the initialization stage of these RAID levels, some RAID management utilities (such as **mdadm**) write to *all* of the blocks on the storage device to ensure that checksums operate properly. This will cause the performance of the SSD to degrade quickly.

As of Red Hat Enterprise Linux 6.4, ext4 and XFS are the only fully-supported file systems that support **discard**. Previous versions of Red Hat Enterprise Linux 6 only ext4 fully supported **discard**. To enable **discard** commands on a device, use the **mount** option **discard**. For example, to mount **/dev/sda2** to **/mnt** with **discard** enabled, run:

```
# mount -t ext4 -o discard /dev/sda2 /mnt
```

By default, ext4 does not issue the **discard** command. This is mostly to avoid problems on devices which may not properly implement the **discard** command. The Linux **swap** code will issue **discard** commands to **discard**-enabled devices, and there is no option to control this behavior.

21.2. Tuning Considerations

This section describes several factors to consider when configuring settings that may affect SSD performance.

I/O Scheduler

Any I/O scheduler should perform well with most SSDs. However, as with any other storage type, Red Hat recommends benchmarking to determine the optimal configuration for a given workload.

When using SSDs, Red Hat advises changing the I/O scheduler only for benchmarking particular workloads. For more information about the different types of I/O schedulers, refer to the *I/O Tuning Guide* (also provided by Red Hat). The following kernel document also contains instructions on how to switch between I/O schedulers:

/usr/share/doc/kernel-*version*/Documentation/block/switching-sched.txt

As of Red Hat Enterprise Linux 7.0, the default I/O scheduler is now Deadline, except for use with SATA drives. In the case of SATA drives, CFQ is the default I/O scheduler. For faster storage, deadline can outperform CFQ leading to better I/O performance without the need for specific tuning. It is possible, however, that default is not right for some disks (such as SAS rotational disks). In this case the I/O scheduler will need to be changed to CFQ.

Virtual Memory

Like the I/O scheduler, virtual memory (VM) subsystem requires no special tuning. Given the fast nature of I/O on SSD, it should be possible to turn down the **vm_dirty_background_ratio** and **vm_dirty_ratio** settings, as increased write-out activity should not negatively impact the latency of other operations on the disk. However, this can generate *more overall I/O* and so is not generally recommended without workload-specific testing.

Swap

An SSD can also be used as a swap device, and is likely to produce good page-out/page-in performance.

Chapter 22. Write Barriers

A *write barrier* is a kernel mechanism used to ensure that file system metadata is correctly written and ordered on persistent storage, even when storage devices with volatile write caches lose power. File systems with write barriers enabled also ensure that data transmitted via **fsync()** is persistent throughout a power loss.

Enabling write barriers incurs a substantial performance penalty for some applications. Specifically, applications that use **fsync()** heavily or create and delete many small files will likely run much slower.

22.1. Importance of Write Barriers

File systems take great care to safely update metadata, ensuring consistency. Journalled file systems bundle metadata updates into transactions and send them to persistent storage in the following manner:

1. First, the file system sends the body of the transaction to the storage device.
2. Then, the file system sends a commit block.
3. If the transaction and its corresponding commit block are written to disk, the file system assumes that the transaction will survive any power failure.

However, file system integrity during power failure becomes more complex for storage devices with extra caches. Storage target devices like local S-ATA or SAS drives may have write caches ranging from 32MB to 64MB in size (with modern drives). Hardware RAID controllers often contain internal write caches. Further, high end arrays, like those from NetApp, IBM, Hitachi and EMC (among others), also have large caches.

Storage devices with write caches report I/O as "complete" when the data is in cache; if the cache loses power, it loses its data as well. Worse, as the cache de-stages to persistent storage, it may change the original metadata ordering. When this occurs, the commit block may be present on disk without having the complete, associated transaction in place. As a result, the journal may replay these uninitialized transaction blocks into the file system during post-power-loss recovery; this will cause data inconsistency and corruption.

How Write Barriers Work

Write barriers are implemented in the Linux kernel via storage write cache flushes before and after the I/O, which is *order-critical*. After the transaction is written, the storage cache is flushed, the commit block is written, and the cache is flushed again. This ensures that:

- The disk contains all the data.
- No re-ordering has occurred.

With barriers enabled, an **fsync()** call will also issue a storage cache flush. This guarantees that file data is persistent on disk even if power loss occurs shortly after **fsync()** returns.

22.2. Enabling/Disabling Write Barriers

To mitigate the risk of data corruption during power loss, some storage devices use battery-backed write caches. Generally, high-end arrays and some hardware controllers use battery-backed write caches. However, because the cache's volatility is not visible to the kernel, Red Hat Enterprise Linux 7 enables write barriers by default on all supported journaling file systems.

Note

Write caches are designed to increase I/O performance. However, enabling write barriers means constantly flushing these caches, which can significantly reduce performance.

For devices with non-volatile, battery-backed write caches and those with write-caching disabled, you can safely disable write barriers at mount time using the **-o nobarrier** option for **mount**. However, some devices do not support write barriers; such devices will log an error message to **/var/log/messages** (refer to Table 22.1, “Write barrier error messages per file system”).

Table 22.1. Write barrier error messages per file system

File System	Error Message
ext3/ext4	**JBD: barrier-based sync failed on *device* - disabling barriers**
XFS	**Filesystem *device* - Disabling barriers, trial barrier write failed**
btrfs	**btrfs: disabling barriers on dev *device***

22.3. Write Barrier Considerations

Some system configurations do not need write barriers to protect data. In most cases, other methods are preferable to write barriers, since enabling write barriers causes a significant performance penalty.

Disabling Write Caches

One way to alternatively avoid data integrity issues is to ensure that no write caches lose data on power failures. When possible, the best way to configure this is to simply disable the write cache. On a simple server or desktop with one or more SATA drives (off a local SATA controller Intel AHCI part), you can disable the write cache on the target SATA drives with the **hdparm** command, as in:

```
# hdparm -W0 /device/
```

Battery-Backed Write Caches

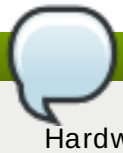
Write barriers are also unnecessary whenever the system uses hardware RAID controllers with battery-backed write cache. If the system is equipped with such controllers and if its component drives have write caches disabled, the controller will advertise itself as a write-through cache; this will inform the kernel that the write cache data will survive a power loss.

Most controllers use vendor-specific tools to query and manipulate target drives. For example, the LSI Megaraid SAS controller uses a battery-backed write cache; this type of controller requires the **MegaCli64** tool to manage target drives. To show the state of all back-end drives for LSI Megaraid SAS, use:

```
# MegaCli64 -LDGetProp  -DskCache  -LAll -aALL
```

To disable the write cache of all back-end drives for LSI Megaraid SAS, use:

```
# MegaCli64 -LDSetProp -DisDskCache -Lall -aALL
```



Note

Hardware RAID cards recharge their batteries while the system is operational. If a system is powered off for an extended period of time, the batteries will lose their charge, leaving stored data vulnerable during a power failure.

High-End Arrays

High-end arrays have various ways of protecting data in the event of a power failure. As such, there is no need to verify the state of the internal drives in external RAID storage.

NFS

NFS clients do not need to enable write barriers, since data integrity is handled by the NFS server side. As such, NFS servers should be configured to ensure data persistence throughout a power loss (whether through write barriers or other means).

Chapter 23. Storage I/O Alignment and Size

Recent enhancements to the SCSI and ATA standards allow storage devices to indicate their preferred (and in some cases, required) *I/O alignment* and *I/O size*. This information is particularly useful with newer disk drives that increase the physical sector size from 512 bytes to 4k bytes. This information may also be beneficial for RAID devices, where the chunk size and stripe size may impact performance.

The Linux I/O stack has been enhanced to process vendor-provided I/O alignment and I/O size information, allowing storage management tools (**parted**, **lvm**, **mkfs.***, and the like) to optimize data placement and access. If a legacy device does not export I/O alignment and size data, then storage management tools in Red Hat Enterprise Linux 7 will conservatively align I/O on a 4k (or larger power of 2) boundary. This will ensure that 4k-sector devices operate correctly even if they do not indicate any required/preferred I/O alignment and size.

Refer to Section 23.2, “Userspace Access” to learn how to determine the information that the operating system obtained from the device. This data is subsequently used by the storage management tools to determine data placement.

The IO scheduler has changed for Red Hat Enterprise Linux 7. Default IO Scheduler is now *Deadline*, except for SATA drives. CFQ is the default IO scheduler for SATA drives. For faster storage, Deadline outperforms CFQ and when it is used there is a performance increase without the need of special tuning.

If default is not right for some disks (for example, SAS rotational disks), then change the IO scheduler to CFQ. This instance will depend on the workload.

23.1. Parameters for Storage Access

The operating system uses the following information to determine I/O alignment and size:

physical_block_size

Smallest internal unit on which the device can operate

logical_block_size

Used externally to address a location on the device

alignment_offset

The number of bytes that the beginning of the Linux block device (partition/MD/LVM device) is offset from the underlying physical alignment

minimum_io_size

The device’s preferred minimum unit for random I/O

optimal_io_size

The device’s preferred unit for streaming I/O

For example, certain 4K sector devices may use a 4K **physical_block_size** internally but expose a more granular 512-byte **logical_block_size** to Linux. This discrepancy introduces potential for misaligned I/O. To address this, the Red Hat Enterprise Linux 7 I/O stack will attempt to start all data areas on a naturally-aligned boundary (**physical_block_size**) by making sure it accounts for any alignment_offset if the beginning of the block device is offset from the underlying physical alignment.

Storage vendors can also supply *I/O hints* about the preferred minimum unit for random I/O (**minimum_io_size**) and streaming I/O (**optimal_io_size**) of a device. For example, **minimum_io_size** and **optimal_io_size** may correspond to a RAID device's chunk size and stripe size respectively.

23.2. Userspace Access

Always take care to use properly aligned and sized I/O. This is especially important for Direct I/O access. Direct I/O should be aligned on a **logical_block_size** boundary, and in multiples of the **logical_block_size**.

With native 4K devices (i.e. **logical_block_size** is 4K) it is now critical that applications perform direct I/O in multiples of the device's **logical_block_size**. This means that applications will fail with native 4k devices that perform 512-byte aligned I/O rather than 4k-aligned I/O.

To avoid this, an application should consult the I/O parameters of a device to ensure it is using the proper I/O alignment and size. As mentioned earlier, I/O parameters are exposed through the both **sysfs** and block device **ioctl** interfaces.

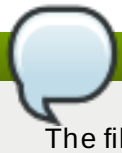
For more details, refer to **man libblkid**. This **man** page is provided by the **libblkid-devel** package.

sysfs Interface

- /sys/block/***disk***/alignment_offset

  or

  /sys/block/***disk***/***partition***/alignment_offset

  Note

  The file location depends on whether the disk is a physical disk (be that a local disk, local RAID, or a multipath LUN) or a virutal disk. The first file location is applicable to physical disks while the second file location is applicable to virtual disks. The reason for this is because virtio-blk will always report an alignment value for the partition. Physical disks may or may not report an alignment value.

- /sys/block/***disk***/queue/physical_block_size
- /sys/block/***disk***/queue/logical_block_size
- /sys/block/***disk***/queue/minimum_io_size
- /sys/block/***disk***/queue/optimal_io_size

The kernel will still export these **sysfs** attributes for "legacy" devices that do not provide I/O parameters information, for example:

Example 23.1. sysfs interface

```
alignment_offset:    0
physical_block_size: 512
```

```
logical_block_size:  512
minimum_io_size:     512
optimal_io_size:     0
```

Block Device ioctls

- **BLKALIGNOFF**: **alignment_offset**
- **BLKPBSZGET**: **physical_block_size**
- **BLKSSZGET**: **logical_block_size**
- **BLKIOMIN**: **minimum_io_size**
- **BLKIOOPT**: **optimal_io_size**

23.3. Standards

This section describes I/O standards used by ATA and SCSI devices.

ATA

ATA devices must report appropriate information via the **IDENTIFY DEVICE** command. ATA devices only report I/O parameters for **physical_block_size**, **logical_block_size**, and **alignment_offset**. The additional I/O hints are outside the scope of the ATA Command Set.

SCSI

I/O parameters support in Red Hat Enterprise Linux 7 requires at least *version 3* of the *SCSI Primary Commands* (SPC-3) protocol. The kernel will only send an *extended inquiry* (which gains access to the **BLOCK LIMITS VPD** page) and **READ CAPACITY(16)** command to devices which claim compliance with SPC-3.

The **READ CAPACITY(16)** command provides the block sizes and alignment offset:

- **LOGICAL BLOCK LENGTH IN BYTES** is used to derive **/sys/block/*disk*/queue/physical_block_size**
- **LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT** is used to derive **/sys/block/*disk*/queue/logical_block_size**
- **LOWEST ALIGNED LOGICAL BLOCK ADDRESS** is used to derive:
  - **/sys/block/*disk*/alignment_offset**
  - **/sys/block/*disk*/*partition*/alignment_offset**

The **BLOCK LIMITS VPD** page (**0xb0**) provides the I/O hints. It also uses **OPTIMAL TRANSFER LENGTH GRANULARITY** and **OPTIMAL TRANSFER LENGTH** to derive:

- **/sys/block/*disk*/queue/minimum_io_size**
- **/sys/block/*disk*/queue/optimal_io_size**

The **sg3_utils** package provides the **sg_inq** utility, which can be used to access the **BLOCK LIMITS VPD** page. To do so, run:

```
# sg_inq -p 0xb0 disk
```

23.4. Stacking I/O Parameters

All layers of the Linux I/O stack have been engineered to propagate the various I/O parameters up the stack. When a layer consumes an attribute or aggregates many devices, the layer must expose appropriate I/O parameters so that upper-layer devices or tools will have an accurate view of the storage as it transformed. Some practical examples are:

- Only one layer in the I/O stack should adjust for a non-zero **alignment_offset**; once a layer adjusts accordingly, it will export a device with an **alignment_offset** of zero.
- A striped Device Mapper (DM) device created with LVM must export a **minimum_io_size** and **optimal_io_size** relative to the stripe count (number of disks) and user-provided chunk size.

In Red Hat Enterprise Linux 7, Device Mapper and Software Raid (MD) device drivers can be used to arbitrarily combine devices with different I/O parameters. The kernel's block layer will attempt to reasonably combine the I/O parameters of the individual devices. The kernel will not prevent combining heterogeneous devices; however, be aware of the risks associated with doing so.

For instance, a 512-byte device and a 4K device may be combined into a single logical DM device, which would have a **logical_block_size** of 4K. File systems layered on such a hybrid device assume that 4K will be written atomically, but in reality it will span 8 logical block addresses when issued to the 512-byte device. Using a 4K **logical_block_size** for the higher-level DM device increases potential for a partial write to the 512-byte device if there is a system crash.

If combining the I/O parameters of multiple devices results in a conflict, the block layer may issue a warning that the device is susceptible to partial writes and/or is misaligned.

23.5. Logical Volume Manager

LVM provides userspace tools that are used to manage the kernel's DM devices. LVM will shift the start of the data area (that a given DM device will use) to account for a non-zero **alignment_offset** associated with any device managed by LVM. This means logical volumes will be properly aligned (**alignment_offset=0**).

By default, LVM will adjust for any **alignment_offset**, but this behavior can be disabled by setting **data_alignment_offset_detection** to **0** in **/etc/lvm/lvm.conf**. Disabling this is not recommended.

LVM will also detect the I/O hints for a device. The start of a device's data area will be a multiple of the **minimum_io_size** or **optimal_io_size** exposed in sysfs. LVM will use the **minimum_io_size** if **optimal_io_size** is undefined (i.e. **0**).

By default, LVM will automatically determine these I/O hints, but this behavior can be disabled by setting **data_alignment_detection** to **0** in **/etc/lvm/lvm.conf**. Disabling this is not recommended.

23.6. Partition and File System Tools

This section describes how different partition and file system management tools interact with a device's I/O parameters.

util-linux-ng's libblkid and fdisk

The **libblkid** library provided with the **util-linux-ng** package includes a programmatic API to access a device's I/O parameters. **libblkid** allows applications, especially those that use Direct I/O, to properly size their I/O requests. The **fdisk** utility from **util-linux-ng** uses **libblkid** to determine the I/O parameters of a device for optimal placement of all partitions. The **fdisk** utility will align all partitions on a 1MB boundary.

parted and libparted

The **libparted** library from **parted** also uses the I/O parameters API of **libblkid**. The Red Hat Enterprise Linux 7 installer (**Anaconda**) uses **libparted**, which means that all partitions created by either the installer or **parted** will be properly aligned. For all partitions created on a device that does not appear to provide I/O parameters, the default alignment will be 1MB.

The heuristics **parted** uses are as follows:

- Always use the reported **alignment_offset** as the offset for the start of the first primary partition.
- If **optimal_io_size** is defined (i.e. not **0**), align all partitions on an **optimal_io_size** boundary.
- If **optimal_io_size** is undefined (i.e. **0**), **alignment_offset** is **0**, and **minimum_io_size** is a power of 2, use a 1MB default alignment.

  This is the catch-all for "legacy" devices which don't appear to provide I/O hints. As such, by default all partitions will be aligned on a 1MB boundary.

Note

Red Hat Enterprise Linux 7 cannot distinguish between devices that don't provide I/O hints and those that do so with **alignment_offset=0** and **optimal_io_size=0**. Such a device might be a single SAS 4K device; as such, at worst 1MB of space is lost at the start of the disk.

File System tools

The different **mkfs.*filesystem*** utilities have also been enhanced to consume a device's I/O parameters. These utilities will not allow a file system to be formatted to use a block size smaller than the **logical_block_size** of the underlying storage device.

Except for **mkfs.gfs2**, all other **mkfs.*filesystem*** utilities also use the I/O hints to layout on-disk data structure and data areas relative to the **minimum_io_size** and **optimal_io_size** of the underlying storage device. This allows file systems to be optimally formatted for various RAID (striped) layouts.

Chapter 24. Setting Up A Remote Diskless System

To set up a basic remote diskless system booted over PXE, you need the following packages:

- **tftp-server**
- **xinetd**
- **dhcp**
- **syslinux**
- **dracut-network**

Note

After installing the **dracut-network** package, add the following line to **/etc/dracut.conf**:

```
add_dracutmodules+="nfs"
```

Remote diskless system booting requires both a **tftp** service (provided by **tftp-server**) and a DHCP service (provided by **dhcp**). The **tftp** service is used to retrieve kernel image and **initrd** over the network via the PXE loader.

Note

SELinux is only supported over NFSv4.2. To use SELinux, NFS must be explicitly enabled in **/etc/sysconfig/nfs** by adding the line:

RPCNFSDARGS="-V 4.2"

Then, in **/var/lib/tftpboot/pxelinux.cfg/default**, change **root=nfs:server-ip:/exported/root/directory** to **root=nfs:server-ip:/exported/root/directory,vers=4.2**.

Finally, reboot the NFS server.

The following sections outline the necessary procedures for deploying remote diskless systems in a network environment.

Important

Some RPM packages have started using file capabilities (such as **setcap** and **getcap**). However, NFS does not currently support these so attempting to install or update any packages that use file capabilities will fail.

24.1. Configuring a tftp Service for Diskless Clients

The **tftp** service is disabled by default. To enable it and allow PXE booting via the network, set the **Disabled** option in **/etc/xinetd.d/tftp** to **no**. To configure **tftp**, perform the following steps:

Procedure 24.1. To configure tftp

1. The **tftp** root directory (**chroot**) is located in **/var/lib/tftpboot**. Copy **/usr/share/syslinux/pxelinux.0** to **/var/lib/tftpboot/**, as in:

   ```
   cp /usr/share/syslinux/pxelinux.0 /var/lib/tftpboot/
   ```

2. Create a **pxelinux.cfg** directory inside the **tftp** root directory:

   ```
   mkdir -p /var/lib/tftpboot/pxelinux.cfg/
   ```

You will also need to configure firewall rules properly to allow **tftp** traffic; as **tftp** supports TCP wrappers, you can configure host access to **tftp** via **/etc/hosts.allow**. For more information on configuring TCP wrappers and the **/etc/hosts.allow** configuration file, refer to the Red Hat Enterprise Linux 7 *Security Guide*; **man hosts_access** also provides information about **/etc/hosts.allow**.

After configuring **tftp** for diskless clients, configure DHCP, NFS, and the exported file system accordingly. Refer to Section 24.2, “Configuring DHCP for Diskless Clients” and Section 24.3, “Configuring an Exported File System for Diskless Clients” for instructions on how to do so.

24.2. Configuring DHCP for Diskless Clients

After configuring a **tftp** server, you need to set up a DHCP service on the same host machine. Refer to the Red Hat Enterprise Linux 7 *Deployment Guide* for instructions on how to set up a DHCP server. In addition, you should enable PXE booting on the DHCP server; to do this, add the following configuration to **/etc/dhcp/dhcp.conf**:

```
allow booting;
allow bootp;
class "pxeclients" {
   match if substring(option vendor-class-identifier, 0, 9) =
"PXEClient";
   next-server server-ip;
   filename "pxelinux.0";
}
```

Replace ***server-ip*** with the IP address of the host machine on which the **tftp** and DHCP services reside. Now that **tftp** and DHCP are configured, all that remains is to configure NFS and the exported file system; refer to Section 24.3, “Configuring an Exported File System for Diskless Clients” for instructions.

Note

When **libvirt** virtual machines are used as the diskless client, **libvirt** provides the DHCP service and the stand alone DHCP server is not used. In this situation, network booting must be enabled with the **bootp file='*filename*'** option in the **libvirt** network configuration, **virsh net-edit**.

24.3. Configuring an Exported File System for Diskless Clients

The root directory of the exported file system (used by diskless clients in the network) is shared via NFS. Configure the NFS service to export the root directory by adding it to **/etc/exports**. For instructions on how to do so, refer to Section 8.7.1, “The **/etc/exports** Configuration File”.

To accommodate completely diskless clients, the root directory should contain a complete Red Hat Enterprise Linux installation. You can synchronize this with a running system via **rsync**, as in:

```
# rsync -a -e ssh --exclude='/proc/*' --exclude='/sys/*' hostname.com:/
/exported/root/directory
```

Replace ***hostname.com*** with the hostname of the running system with which to synchronize via **rsync**. The ***/exported/root/directory*** is the path to the exported file system.

Alternatively, you can also use **yum** with the **--installroot** option to install Red Hat Enterprise Linux to a specific location. For example:

```
yum groupinstall Base --installroot=/exported/root/directory --
releasever=/
```

The file system to be exported still needs to be configured further before it can be used by diskless clients. To do this, perform the following procedure:

Procedure 24.2. Configure file system

1. Configure the exported file system's **/etc/fstab** to contain (at least) the following configuration:

   ```
   none  /tmp  tmpfs defaults 0 0
   tmpfs  /dev/shm tmpfs defaults 0 0
   sysfs  /sys  sysfs defaults 0 0
   proc  /proc  proc  defaults 0 0
   ```

2. Select the kernel that diskless clients should use (**vmlinuz-*kernel-version***) and copy it to the **tftp** boot directory:

   ```
   # cp /boot/vmlinuz-kernel-version /var/lib/tftpboot/
   ```

3. Create the **initrd** (that is, **initramfs-*kernel-version*.img**) with network support:

   ```
   # dracut initramfs-kernel-version.img kernel-version
   ```

4. The initrd's file permissions need to be changed to 600 or the **pxelinux.0** boot loader will fail with a "file not found" error. Do this with the following command:

   ```
   # chmod go-r initramfs-kernel-version.img
   ```

5. Copy the resulting **initramfs-*kernel-version*.img** into the **tftp** boot directory as well.

6. Edit the default boot configuration to use the **initrd** and kernel inside **/var/lib/tftpboot**. This configuration should instruct the diskless client's root to mount the exported file system (***/exported/root/directory***) as read-write. To do this, configure **/var/lib/tftpboot/pxelinux.cfg/default** with the following:

```
default rhel7

label rhel7
  kernel vmlinuz-kernel-version
  append initrd=initramfs-kernel-version.img root=nfs:server-
ip:/exported/root/directory rw
```

   Replace ***server-ip*** with the IP address of the host machine on which the **tftp** and DHCP services reside.

The NFS share is now ready for exporting to diskless clients. These clients can boot over the network via PXE.

Chapter 25. Online Storage Management

It is often desirable to add, remove or re-size storage devices while the operating system is running, and without rebooting. This chapter outlines the procedures that may be used to reconfigure storage devices on Red Hat Enterprise Linux 7 host systems while the system is running. It covers iSCSI and Fibre Channel storage interconnects; other interconnect types may be added it the future.

This chapter focuses on adding, removing, modifying, and monitoring storage devices. It does not discuss the Fibre Channel or iSCSI protocols in detail. For more information about these protocols, refer to other documentation.

This chapter makes reference to various **sysfs** objects. Red Hat advises that the **sysfs** object names and directory structure are subject to change in major Red Hat Enterprise Linux releases. This is because the upstream Linux kernel does not provide a stable internal API. For guidelines on how to reference **sysfs** objects in a transportable way, refer to the document **/usr/share/doc/kernel-doc-*version*/Documentation/sysfs-rules.txt** in the kernel source tree for guidelines.

Warning

Online storage reconfiguration must be done carefully. System failures or interruptions during the process can lead to unexpected results. Red Hat advises that you reduce system load to the maximum extent possible during the change operations. This will reduce the chance of I/O errors, out-of-memory errors, or similar errors occurring in the midst of a configuration change. The following sections provide more specific guidelines regarding this.

In addition, Red Hat recommends that you back up all data before reconfiguring online storage.

25.1. Target Setup

Red Hat Enterprise Linux 7 uses **targetcli** as a front-end for viewing, editing, and saving the configuration of the Linux-IO Target without the need to manipulate the kernel target's configuration files directly. **targetcli** is a command line interface that allows an administrator to export local storage resources (backed by either files, volumes, local SCSI devices, or RAM disks) to remote systems. It has a tree-based layout, includes built-in tab-completion, and provides full auto-complete support and inline documentation.

Note

targetcli's hierachy does not always match up to the kernel interface. This is because it is designed to be simplified where possible.

Important

To ensure that the changes made in **targetcli** are persistent, start and enable the target service:

```
~]# systemctl start target
~]# systemctl enable target
```

25.1.1. Install and run targetcli

To install **targetcli**, run:

```
# yum install targetcli
```

Start the target service:

```
# systemctl start target
```

Configure target to persistantly start at boot time:

```
# systemctl enable target
```

To start using **targetcli**, run **targetcli** and to get a layout of the tree interface, run **ls**:

```
# targetcli
:
/> ls
o- /.....................................[...]
  o- backstores..........................[...]
  | o- block..............[Storage Objects: 0]
  | o- fileio.............[Storage Objects: 0]
  | o- pscsi..............[Storage Objects: 0]
  | o- ramdisk............[Storage Ojbects: 0]
  o- iscsi......................[Targets: 0]
  o- loopback...................[Targets: 0]
```

Note

In Red Hat Enterprise Linux 7.0, running a **targetcli** command from bash (for example, **targetcli iscsi/ create**) would not work, but would also give no error code. This has been fixed in Red Hat Enterprise Linux 7.1 to provide an error status code, thus making it more useful to use with shell scripts.

25.1.2. Create a Backstore

Backstores enable support for different methods of storing an exported LUN's data on the local machine. Creating a storage object defines the resources the backstore will use.

Note

In Red Hat Enterprise Linux 6 the term 'backing-store' is used to refer to the mappings created. However, to avoid confusion between the various ways 'backstores' can be used, in Red Hat Enterprise Linux 7 the term 'storage objects' refers to the mappings created and 'backstores' is used to describe the different types of backing devices.

The backstore devices that LIO supports are:

FILEIO (Linux file-backed storage)

FILEIO storage objects can support either **write_back** or **write_thru** operation. The **write_back** enables the local file system cache. This improves performance but increases the risk of data loss. It is recommended to use **write_back=false** to disable **write_back** in favor of **write_thru**.

To create a fileio storage object, run the command **/backstores/fileio create *file_name file_location file_size* write_back=false**. For example:

```
/> /backstores/fileio create file1 /tmp/disk1.img 200M
write_back=false
Created fileio file1 with size 209715200
```

BLOCK (Linux BLOCK devices)

The block driver allows the use of any block device that appears in the **/sys/block** to be used with LIO. This includes physical devices (for example, HDDs, SSDs, CDs, DVDs) and logical devices (for example, software or hardware RAID volumes, or LVM volumes).

Note

BLOCK backstores usually provide the best performance.

To create a BLOCK backstore using the **/dev/sdb** block device, use the following command:

```
/> /backstores/block create name=block_backend dev=/dev/sdb
Generating a wwn serial.
Created block storage object block_backend using /dev/sdb.
```

PSCSI (Linux pass-through SCSI devices)

Any storage object that supports direct pass-through of SCSI commands without SCSI emulation, and with an underlying SCSI device that appears with lsscsi in **/proc/scsi/scsi** (such as a SAS hard drive) can be configured as a backstore. SCSI-3 and higher is supported with this subsystem.

Warning

PSCSI should only be used by advanced users. Advanced SCSI commands such as for Aysmmetric Logical Unit Assignment (ALUAs) or Persistent Reservations (for example, those used by VMware ESX, and vSphere) are usually not implemented in the device firmware and can cause malfunctions or crashes. When in doubt, use BLOCK for production setups instead.

To create a PSCSI backstore for a physical SCSI device, a **TYPE_ROM** device using **/dev/sr0** in this example, use:

```
/> backstores/pscsi/ create name=pscsi_backend dev=/dev/sr0
Generating a wwn serial.
Created pscsi storage object pscsi_backend using /dev/sr0
```

Memory Copy RAM disk (Linux RAMDISK_MCP)

Memory Copy RAM disks (**ramdisk**) provide RAM disks with full SCSI emulation and separate memory mappings using memory copy for initiators. This provides capability for multi-sessions and is particularly useful for fast, volatile mass storage for production purposes.

To create a 1GB RAM disk backstore, use the following command:

```
/> backstores/ramdisk/ create name=rd_backend size=1GB
Generating a wwn serial.
Created rd_mcp ramdisk rd_backend with size 1GB.
```

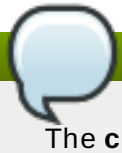
25.1.3. Create an iSCSI Target

To create an iSCSI target:

Procedure 25.1. Create an iSCSI target

1. Run **targetcli**.
2. Move into the iSCSI configuration path:

```
/> iscsi/
```



Note

The **cd** command is also accepted to change directories, as well as simply listing the path to move into.

3. Create an iSCSI target using a default target name.

```
/iscsi> create
Created target
iqn.2003-01.org.linux-iscsi.hostname.x8664:sn.78b473f296ff
Created TPG1
```

Or create an iSCSI target using a specified name.

```
/iscsi > create iqn.2006-04.com.example:444
Created target iqn.2006-04.com.example:444
Created TPG1
```

4. Verify that the newly created target is visible when targets are listed with **ls**.

```
/iscsi > ls
o- iscsi.....................................[1 Target]
    o- iqn.2006-04.com.example:444.............[1 TPG]
        o- tpg1.........................[enabled, auth]
            o- acls.............................[0 ACL]
            o- luns.............................[0 LUN]
            o- portals.....................[0 Portal]
```

Note

As of Red Hat Enterprise Linux 7.1, whenever a target is created, a default portal is also created.

25.1.4. Configure an iSCSI Portal

To configure an iSCSI portal, an iSCSI target must first be created and associated with a TPG. For instructions on how to do this, refer to Section 25.1.3, “Create an iSCSI Target”.

Note

As of Red Hat Enterprise Linux 7.1 when an iSCSI target is created, a default portal is created as well. This portal is set to listen on all IP addresses with the default port number (that is, 0.0.0.0:3260). To remove this and add only specified portals, use **/iscsi/*iqn-name*/tpg1/portals delete ip_address=0.0.0.0 ip_port=3260** then create a new portal with the required information.

Procedure 25.2. Create an iSCSI Portal

1. Move into the TPG.

```
/iscsi> iqn.2006-04.example:444/tpg1/
```

2. There are two ways to create a portal: create a default portal, or create a portal specifying what IP address to listen to.

Creating a default portal uses the default iSCSI port 3260 and allows the target to listen on all IP addresses on that port.

```
/iscsi/iqn.20...mple:444/tpg1> portals/ create
Using default IP port 3260
Binding to INADDR_Any (0.0.0.0)
Created network portal 0.0.0.0:3260
```

To create a portal specifying what IP address to listen to, use the following command.

```
/iscsi/iqn.20...mple:444/tpg1> portals/ create 192.168.122.137
Using default IP port 3260
Created network portal 192.168.122.137:3260
```

3. Verify that the newly created portal is visible with the **ls** command.

```
/iscsi/iqn.20...mple:444/tpg1> ls
o- tpg.............................. [enambled, auth]
    o- acls ....................................[0 ACL]
    o- luns ....................................[0 LUN]
    o- portals .................................[1 Portal]
        o- 192.168.122.137:3260.....................[OK]
```

25.1.5. Configure LUNs

To configure LUNs, first create storage objects. See Section 25.1.2, “Create a Backstore” for more information.

Procedure 25.3. Configure LUNs

1. Create LUNs of already created storage objects.

```
/iscsi/iqn.20...mple:444/tpg1> luns/ create
/backstores/ramdisk/ramdisk1
Created LUN 0.

/iscsi/iqn.20...mple:444/tpg1> luns/ create /backstores/block/block1
Created LUN 1.

/iscsi/iqn.20...mple:444/tpg1> luns/ create /backstores/fileio/file1
Created LUN 2.
```

2. Show the changes.

```
/iscsi/iqn.20...mple:444/tpg1> ls
o- tpg.............................. [enambled, auth]
    o- acls ....................................[0 ACL]
    o- luns ....................................[3 LUNs]
    |  o- lun0.....................[ramdisk/ramdisk1]
    |  o- lun1..............[block/block1 (/dev/vdb1)]
    |  o- lun2................[fileio/file1 (/foo.img)]
    o- portals .................................[1 Portal]
        o- 192.168.122.137:3260.....................[OK]
```

Note

Be aware that the default LUN name starts at 0, as opposed to 1 as was the case when using **tgtd** in Red Hat Enterprise Linux 6.

Important

By default, LUNs are created with read-write permissions. In the event that a new LUN is added after ACLs have been created that LUN will be automatically mapped to all available ACLs. This can cause a security risk. Use the following procedure to create a LUN as read-only.

Procedure 25.4. Create a read-only LUN

1. To create a LUN with read-only permissions, first use the following command:

```
/> set global auto_add_mapped_luns=false
Parameter auto_add_mapped_luns is now 'false'.
```

This prevents the auto mapping of LUNs to existing ACLs allowing the manual mapping of LUNs.

2. Next, manually create the LUN with the command **iscsi/*target_iqn_name*/tpg1/acls/*initiator_iqn_name*/ create mapped_lun=*next_sequential_LUN_number* tpg_lun_or_backstore=*backstore* write_protect=1**.

```
/> iscsi/iqn.2015-06.com.redhat:target/tpg1/acls/iqn.2015-
06.com.redhat:initiator/ create mapped_lun=1
tpg_lun_or_backstore=/backstores/block/block2 write_protect=1
Created LUN 1.
Created Mapped LUN 1.
/> ls
o- / ..................................................... [...]
  o- backstores ........................................... [...]
  <snip>
  o- iscsi ......................................... [Targets: 1]
  | o- iqn.2015-06.com.redhat:target ................... [TPGs: 1]
  |   o- tpg1 ............................ [no-gen-acls, no-auth]
  |     o- acls ....................................... [ACLs: 2]
  |     | o- iqn.2015-06.com.redhat:initiator .. [Mapped LUNs: 2]
  |     | | o- mapped_lun0 .............. [lun0 block/disk1 (rw)]
  |     | | o- mapped_lun1 .............. [lun1 block/disk2 (ro)]
  |     o- luns ....................................... [LUNs: 2]
  |     | o- lun0 ..................... [block/disk1 (/dev/vdb)]
  |     | o- lun1 ..................... [block/disk2 (/dev/vdc)]
  <snip>
```

The mapped_lun1 line now has (ro) at the end (unlike mapped_lun0's (rw)) stating that it is read-only.

25.1.6. Configure ACLs

Create an ACL for each initiator that will be connecting. This enforces authentication when that initiator connects, allowing only LUNs to be exposed to each initiator. Usually each initator has exclusive access to a LUN. Both targets and initiators have unique identifying names. The initiator's unique name must be known to configure ACLs. For open-iscsi initiators, this can be found in **/etc/iscsi/initiatorname.iscsi**.

Procedure 25.5. Configure ACLs

1. Move into the acls directory.

```
/iscsi/iqn.20...mple:444/tpg1> acls/
```

2. Create an ACL. Either use the initiator name found in **/etc/iscsi/initiatorname.iscsi** on the initiator, or if using a name that is easier to remember, refer to Section 25.2, “Create an iSCSI Initiator” to ensure ACL matches the initiator. For example:

```
/iscsi/iqn.20...444/tpg1/acls> create iqn.2006-
04.com.example.foo:888
Created Node ACL for iqn.2006-04.com.example.foo:888
Created mapped LUN 2.
Created mapped LUN 1.
Created mapped LUN 0.
```

Note

The above example's behavior depends on the setting used. In this case, the global setting **auto_add_mapped_luns** is used. This automatically maps LUNs to any created ACL.

3. Show the changes.

```
/iscsi/iqn.20...444/tpg1/acls> ls
o- acls ..................................................[1 ACL]
    o- iqn.2006-04.com.example.foo:888 ....[3 Mapped LUNs, auth]
        o- mapped_lun0 .............[lun0 ramdisk/ramdisk1 (rw)]
        o- mapped_lun1 ................[lun1 block/block1 (rw)]
        o- mapped_lun2 ................[lun2 fileio/file1 (rw)]
```

25.1.7. Fibre Channel over Ethernet (FCoE) Target Setup

In addition to mounting LUNs over FCoE, as described in Section 25.4, “Configuring a Fibre Channel over Ethernet Interface”, exporting LUNs to other machines over FCoE is also supported with the aid of **targetcli**.

Important

Before proceeding, refer to Section 25.4, “Configuring a Fibre Channel over Ethernet Interface” and verify that basic FCoE setup is completed, and that **fcoeadm -i** displays configured FCoE interfaces.

Procedure 25.6. Configure FCoE target

1. Setting up an FCoE target requires the installation of the **targetcli** package, along with its dependencies. Refer to Section 25.1, “Target Setup” for more information on **targetcli** basics and set up.

2. Create an FCoE target instance on an FCoE interface.

```
/> tcm_fc/ create 00:11:22:33:44:55:66:77
```

   If FCoE interfaces are present on the system, tab-completing after **create** will list available interfaces. If not, ensure **fcoeadm -i** shows active interfaces.

3. Map a backstore to the target instance.

   Example 25.1. Example of mapping a backstore to the target instance

```
/> tcm_fc/00:11:22:33:44:55:66:77
```

```
/> luns/ create /backstores/fileio/example2
```

4. Allow access to the LUN from an FCoE initiator.

```
/> acls/ create 00:99:88:77:66:55:44:33
```

   The LUN should now be accessible to that initiator.

5. To make the changes persistant across reboots, use the **saveconfig** command and type **yes** when prompted. If this is not done the configuration will be lost after rebooting.

6. Exit **targetcli** by typing **exit** or entering **ctrl**+**D**.

25.1.8. Remove objects with `targetcli`

To remove an backstore use the command:

```
/> /backstores/backstore-type/backstore-name
```

To remove parts of an iSCSI target, such as an ACL, use the following command:

```
/> /iscsi/iqn-name/tpg/acls/ delete iqn-name
```

To remove the entire target, including all ACLs, LUNs, and portals, use the following command:

```
/> /iscsi delete iqn-name
```

25.1.9. `targetcli` References

For more information on **targetcli**, refer to the following resources:

man targetcli

The **targetcli** man page. It includes an example walk through.

The Linux SCSI Target Wiki

http://linux-iscsi.org/wiki/Targetcli

Screencast by Andy Grover

https://www.youtube.com/watch?v=BkBGTBadOO8

Note

This was uploaded on February 28, 2012. As such, the service name has changed from **targetcli** to **target**.

25.2. Create an iSCSI Initiator

After creating a target with **targetcli** as in Section 25.1, “Target Setup” use the **iscsiadm** utility to set up an initiator.

Note

In Red Hat Enterprise Linux 7, the iSCSI service is lazily started by default. That is, should an **iscsiadm** command be issued the service will start.

Procedure 25.7. Create an iSCSI Initiator

1. Install **iscsi-initiator-utils**.

```
~]$ sudo yum install iscsi-initiator-utils
```

2. If a custom name was given to the ACL in Section 25.1.6, “Configure ACLs”, then change the **/etc/iscsi/initiatorname.isci** file to match.

```
~]$ sudo vim /etc/iscsi/initiatorname.iscsi
~]$ cat /etc/iscsi/initiatorname.iscsi
InitiatorName=iqn.2006-04.com.example.foo
```

3. Discover the target.

```
~]$ sudo iscsiadm -m discovery -t st -p target-ip-address
10.64.24.179:3260,1 iqn.2006-04.com.example:3260
```

4. Log in to the target with the target iqn name found in the above step.

```
~]$ sudo iscsiadm -m node -T iqn.2006-04.com.example:3260 -l
Logging in to [iface: default, target: iqn.2006-
04.com.example:3260, portal: 10.64.24.179,3260] (multiple)
Login to [iface: default, target: iqn.2006-04.com.example:3260,
portal: 10.64.24.179,3260] successful.
```

This procedure can be followed for any number of initators connected to the same LUN so long as their specific initiator names are added to the ACL as described in Section 25.1.6, “Configure ACLs”.

25.3. Fibre Channel

This section discusses the Fibre Channel API, native Red Hat Enterprise Linux 7 Fibre Channel drivers, and the Fibre Channel capabilities of these drivers.

25.3.1. Fibre Channel API

Below is a list of **/sys/class/** directories that contain files used to provide the userspace API. In each item, host numbers are designated by ***H***, bus numbers are ***B***, targets are ***T***, logical unit numbers (LUNs) are ***L***, and remote port numbers are ***R***.

Important

If your system is using multipath software, Red Hat recommends that you consult your hardware vendor before changing any of the values described in this section.

Transport: /sys/class/fc_transport/target*H*:*B*:*T*/

- **port_id** — 24-bit port ID/address
- **node_name** — 64-bit node name
- **port_name** — 64-bit port name

Remote Port: /sys/class/fc_remote_ports/rport-*H*:*B*-*R*/

- **port_id**
- **node_name**
- **port_name**
- **dev_loss_tmo** — number of seconds to wait before marking a link as "bad". Once a link is marked bad, I/O running on its corresponding path (along with any new I/O on that path) will be failed.

  The default **dev_loss_tmo** value varies, depending on which driver/device is used. If a Qlogic adapter is used, the default is 35 seconds, while if an Emulex adapter is used, it is 30 seconds. The **dev_loss_tmo** value can be changed via the **scsi_transport_fc** module parameter **dev_loss_tmo**, although the driver can override this timeout value.

  The maximum **dev_loss_tmo** value is 600 seconds. If **dev_loss_tmo** is set to zero or any value greater than 600, the driver's internal timeouts will be used instead.
- **fast_io_fail_tmo** — length of time to wait before failing I/O executed when a link problem is detected. I/O that reaches the driver will fail. If I/O is in a blocked queue, it will not be failed until **dev_loss_tmo** expires and the queue is unblocked.

Host: /sys/class/fc_host/host*H*/

- **port_id**

- **issue_lip** — instructs the driver to rediscover remote ports.

25.3.2. Native Fibre Channel Drivers and Capabilities

Red Hat Enterprise Linux 7 ships with the following native Fibre Channel drivers:

- **lpfc**
- **qla2xxx**
- **zfcp**
- **bfa**

Table 25.1, “Fibre Channel API Capabilities” describes the different Fibre Channel API capabilities of each native Red Hat Enterprise Linux 7 driver. X denotes support for the capability.

Table 25.1. Fibre Channel API Capabilities

	lpfc	qla2xxx	zfcp	bfa
Transport **port_id**	X	X	X	X
Transport **node_name**	X	X	X	X
Transport **port_name**	X	X	X	X
Remote Port **dev_loss_tmo**	X	X	X	X
Remote Port **fast_io_fail_tmo**	X	X [a]	X [b]	X
Host **port_id**	X	X	X	X
Host **issue_lip**	X	X		X

[a] Supported as of Red Hat Enterprise Linux 5.4
[b] Supported as of Red Hat Enterprise Linux 6.0

25.4. Configuring a Fibre Channel over Ethernet Interface

Setting up and deploying a Fibre Channel over Ethernet (FCoE) interface requires two packages:

- **fcoe-utils**
- **lldpad**

Once these packages are installed, perform the following procedure to enable FCoE over a virtual LAN (VLAN):

Procedure 25.8. Configuring an Ethernet interface to use FCoE

1. To configure a new VLAN, make a copy of an existing network script, for example **/etc/fcoe/cfg-eth0**, and change the name to the Ethernet device that supports FCoE. This provides you with a default file to configure. Given that the FCoE device is **eth*X***, run:

```
# cp /etc/fcoe/cfg-eth0  /etc/fcoe/cfg-ethX
```

Modify the contents of **cfg-ethX** as needed. Notably, set **DCB_REQUIRED** to **no** for networking interfaces that implement a hardware Data Center Bridging Exchange (DCBX) protocol client.

2. If you want the device to automatically load during boot time, set **ONBOOT=yes** in the corresponding **/etc/sysconfig/network-scripts/ifcfg-ethX** file. For example, if the FCoE device is eth2, edit **/etc/sysconfig/network-scripts/ifcfg-eth2** accordingly.

3. Start the data center bridging daemon (**dcbd**) by running:

```
# systemctl start lldpad
```

4. For networking interfaces that implement a hardware DCBX client, skip this step.

   For interfaces that require a software DCBX client, enable data center bridging on the Ethernet interface by running:

```
# dcbtool sc ethX dcb on
```

   Then, enable FCoE on the Ethernet interface by running:

```
# dcbtool sc ethX app:fcoe e:1
```

   Note that these commands only work if the **dcbd** settings for the Ethernet interface were not changed.

5. Load the FCoE device now using:

```
# ifconfig ethX up
```

6. Start FCoE using:

```
# systemctl start fcoe
```

   The FCoE device appears soon if all other settings on the fabric are correct. To view configured FCoE devices, run:

```
# fcoeadm -i
```

After correctly configuring the Ethernet interface to use FCoE, Red Hat recommends that you set FCoE and **lldpad** to run at startup. To do so, use **chkconfig**, as in:

```
# systemctl enable lldpad
```

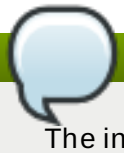
```
# systemctl enable fcoe
```

Note

Running the **# systemctl stop fcoe** command stops the daemon, but does not reset the configuration of FCoE interfaces. To do so, run the **# systemctl -s SIGHUP kill fcoe** command.

As of Red Hat Enterprise Linux 7, Network Manager has the ability to query and set the DCB settings of a DCB capable Ethernet interface.

25.5. Configuring an FCoE Interface to Automatically Mount at Boot



Note

The instructions in this section are available in **/usr/share/doc/fcoe-utils-*version*/README** as of Red Hat Enterprise Linux 6.1. Refer to that document for any possible changes throughout minor releases.

You can mount newly discovered disks via **udev** rules, **autofs**, and other similar methods. Sometimes, however, a specific service might require the FCoE disk to be mounted at boot-time. In such cases, the FCoE disk should be mounted *as soon as* the **fcoe** service runs and *before* the initiation of any service that requires the FCoE disk.

To configure an FCoE disk to automatically mount at boot, add proper FCoE mounting code to the startup script for the **fcoe** service. The **fcoe** startup script is **/etc/init.d/fcoe**.

The FCoE mounting code is different per system configuration, whether you are using a simple formatted FCoE disk, LVM, or multipathed device node.

Example 25.2. FCoE mounting code

The following is a sample FCoE mounting code for mounting file systems specified via wild cards in **/etc/fstab**:

```
mount_fcoe_disks_from_fstab()
 {
     local timeout=20
     local done=1
     local fcoe_disks=($(egrep 'by-path\/fc-.*_netdev' /etc/fstab | cut
-d ' ' -f1))

     test -z $fcoe_disks && return 0

     echo -n "Waiting for fcoe disks . "
     while [ $timeout -gt 0 ]; do
  for disk in ${fcoe_disks[*]}; do
   if ! test -b $disk; then
    done=0
    break
   fi
  done

  test $done -eq 1 && break;
  sleep 1
  echo -n ". "
  done=1
  let timeout--
     done

     if test $timeout -eq 0; then
```

```
  echo "timeout!"
     else
  echo "done!"
     fi

     # mount any newly discovered disk
     mount -a 2>/dev/null
 }
```

The **mount_fcoe_disks_from_fstab** function should be invoked *after* the **fcoe** service script starts the **fcoemon** daemon. This will mount FCoE disks specified by the following paths in **/etc/fstab**:

```
/dev/disk/by-path/fc-0xXX:0xXX /mnt/fcoe-disk1 ext3  defaults,_netdev
0 0
/dev/disk/by-path/fc-0xYY:0xYY /mnt/fcoe-disk2 ext3  defaults,_netdev
0 0
```

Entries with **fc-** and **_netdev** sub-strings enable the **mount_fcoe_disks_from_fstab** function to identify FCoE disk mount entries. For more information on **/etc/fstab** entries, refer to **man 5 fstab**.

Note

The **fcoe** service does not implement a timeout for FCoE disk discovery. As such, the FCoE mounting code should implement its own timeout period.

25.6. iSCSI

This section describes the iSCSI API and the **iscsiadm** utility. Before using the **iscsiadm** utility, install the **iscsi-initiator-utils** package first by running **yum install iscsi-initiator-utils**.

In Red Hat Enterprise Linux 7, the iSCSI service is lazily started by default. If root is not on an iSCSI device or there are no nodes marked with **node.startup = automatic** then the iSCSI service will not start until an **iscsiadm** command is run that requires iscsid or the iscsi kernel modules to be started. For example, running the discovery command **iscsiadm -m discovery -t st -p ip:port** will cause iscsiadmin to start the iSCSI service.

To force the iscsid daemon to run and iSCSI kernel modules to load, run **service iscsid force-start**.

25.6.1. iSCSI API

To get information about running sessions, run:

```
# iscsiadm -m session -P 3
```

This command displays the session/device state, session ID (sid), some negotiated parameters, and the SCSI devices accessible through the session.

For shorter output (for example, to display only the sid-to-node mapping), run:

```
# iscsiadm -m session -P 0
```

or

```
# iscsiadm -m session
```

These commands print the list of running sessions with the format:

```
driver [sid] target_ip:port,target_portal_group_tag proper_target_name
```

Example 25.3. Output of the `iscisadm -m session` command

For example:

```
# iscsiadm -m session

tcp [2] 10.15.84.19:3260,2 iqn.1992-08.com.netapp:sn.33615311
tcp [3] 10.15.85.19:3260,3 iqn.1992-08.com.netapp:sn.33615311
```

For more information about the iSCSI API, refer to **/usr/share/doc/iscsi-initiator-utils-*version*/README**.

25.7. Persistent Naming

Red Hat Enterprise Linux provides a number of ways to identify storage devices. It is important to use the correct option to identify each device when used in order to avoid inadvertently accessing the wrong device, particularly when installing to or reformatting drives.

25.7.1. `/dev/sd*` and their Major and Minor Numbers

Storage devices managed by the **sd** driver are identified internally by a collection of major device numbers and their associated minor numbers. The major device numbers used for this purpose are not in a contiguous range. Each storage device is represented by a major number and a range of minor numbers, which are used to identify either the entire device or a partition within the device. There is a direct association between the major and minor numbers allocated to a device and numbers in the form of **sd<*letter(s)*><*optional number(s)*>**. Whenever the **sd** driver detects a new device, an available major number and minor number range is allocated. Whenever a device is removed from the operating system, the major number and minor number range is freed for later reuse.

The major and minor number range and associated **sd** names are allocated for each device when it is detected. This means that the association between the major and minor number range and associated **sd** names can change if the order of device detection changes. Although this is unusual with some hardware configurations (for example, with an internal SCSI controller and disks that have thier SCSI target ID assigned by their physical location within a chassis), it can nevertheless occur. Examples of situations where this can happen are as follows:

- A disk may fail to power up or respond to the SCSI controller. This will result in it not being detected by the normal device proble. The disk will not be accessible to the system and subsequent devices will have their major and minor number range, including the associated **sd**

names shifted down. For example, should a disk normally referred to as **sdb** is not detected, a disk that is normally referred to as **sdc** would instead appear as **sdb**.

- A SCSI controller (host bus adapter, or HBA) may fail to initialize, causing all disks connected to that HBA to not be detected. Any disks connected to subsequently probed HBAs would be assigned different major and minor number ranges, and different associated **sd** names.
- The order of driver initialization could change if different types of HBAs are present in the system. This would cause the disks connected to those HBAs to be detected in a different order. This can also occur if HBAs are moved to different PCI slots on the system.
- Disks connected to the system with Fibre Channel, iSCSI, or FCoE adapters might be inaccessible at the time the storage devices are probed, due to a storage array or intervening switch being powered off, for example. This could occur when a system reboots after a power failure, if the storage array takes longer to come online than the system take to boot. Although some Fibre Channel drivers support a mechanism to specify a persistent SCSI target ID to WWPN mapping, this will not cause the major and minor number ranges, and the associated **sd** names to be reserved, it will only provide consistent SCSI target ID numbers.

These reasons make it undesireable to use the major and minor number range or the associated **sd** names when referring to devices, such as in the **/etc/fstab** file. There is the possibility that the wrong device will be mounted and data corruption could result.

Occassionally, however, it is still necessary to refer to the **sd** names even when another mechanism is used (such as when errors are reported by a device). This is because the Linux kernel uses **sd** names (and also SCSI host/channel/target/LUN tuples) in kernel messages regarding the device.

25.7.2. WWID

The *World Wide Identifier* (WWID) can be used in reliably identifying devices. It is a persistent, system-independent ID that the SCSI Standard requires from all SCSI devices. The WWID identifier is guaranteed to be unique for every storage device, and independent of the path that is used to access the device.

This identifier can be obtained by issuing a SCSI Inquiry to retrieve the *Device Identification Vital Product Data* (page **0x83**) or *Unit Serial Number* (page **0x80**). The mappings from these WWIDs to the current **/dev/sd** names can be seen in the symlinks maintained in the **/dev/disk/by-id/** directory.

> **Example 25.4. WWID**
>
> For example, a device with a page **0x83** identifier would have:
>
> ```
> scsi-3600508b400105e210000900000490000 -> ../../sda
> ```
>
> Or, a device with a page **0x80** identifier would have:
>
> ```
> scsi-SSEAGATE_ST373453LW_3HW1RHM6 -> ../../sda
> ```

Red Hat Enterprise Linux automatically maintains the proper mapping from the WWID-based device name to a current **/dev/sd** name on that system. Applications can use the **/dev/disk/by-id/** name to reference the data on the disk, even if the path to the device changes, and even when accessing the device from different systems.

If there are multiple paths from a system to a device, **device-mapper-multipath** uses the WWID to detect this. **Device-mapper-multipath** then presents a single "pseudo-device" in **/dev/mapper/wwid**, such as **/dev/mapper/3600508b400105df70000e00000ac0000**.

The command **multipath -l** shows the mapping to the non-persistent identifiers: ***Host*:*Channel*:*Target*:*LUN***, **/dev/sd** name, and the **major:minor** number.

```
3600508b400105df70000e00000ac0000 dm-2 vendor,product
[size=20G][features=1 queue_if_no_path][hwhandler=0][rw]
\_ round-robin 0 [prio=0][active]
 \_ 5:0:1:1 sdc 8:32  [active][undef]
 \_ 6:0:1:1 sdg 8:96  [active][undef]
\_ round-robin 0 [prio=0][enabled]
 \_ 5:0:0:1 sdb 8:16  [active][undef]
 \_ 6:0:0:1 sdf 8:80  [active][undef]
```

Device-mapper-multipath automatically maintains the proper mapping of each WWID-based device name to its corresponding **/dev/sd** name on the system. These names are persistent across path changes, and they are consistent when accessing the device from different systems.

When the **user_friendly_names** feature (of **device-mapper-multipath**) is used, the WWID is mapped to a name of the form **/dev/mapper/mpath*n***. By default, this mapping is maintained in the file **/etc/multipath/bindings**. These **mpathn** names are persistent as long as that file is maintained.

Important

If you use **user_friendly_names**, then additional steps are required to obtain consistent names in a cluster. Refer to the Consistent Multipath Device Names in a Cluster section in the *Using DM Multipath Configuration and Administration* book.

In addition to these persistent names provided by the system, you can also use **udev** rules to implement persistent names of your own, mapped to the WWID of the storage.

25.7.3. Device Names Managed by the udev mechanism (/dev/disk/by-*)

The **udev** mechanism consists of three major components:

The kernel

Generates events that are sent to user space when devices are added, removed, or changed.

The udevd daemon

Receives the events.

The udev rules

Specifies the action to take when the **udev** daemon receives the kernel events.

This mechanism is used for all types of devices in Linux, not just for storage devices. In the case of storage devices, Red Hat Enterprise Linux contains **udev** rules that create symbolic links in the **/dev/disk/** directory allowing storage devices to be referred to by their contents, a unique identifier, their serial number, or the hardware path used to access the device.

/dev/disk/by-label

Entries in this directory provide a symbolic name that refers to the storage device by a label in the contents (that is, the data) stored on the device. The **blkid** program is used to read data from the device and determine a name (that is, a label) for the device. For example:

```
/dev/disk/by-label/Boot
```

Note

The information is obtained from the contents (that is, the data) on the device so if the contents are copied to another device, the label will remain the same.

The label can also be used to refer to the device in **/etc/fstab** using the following syntax:

```
LABEL=Boot
```

/dev/disk/by-uuid

Entries in this directory provide a symbolic name that refers to the storage device by a unique identifier in the contents (that is, the data) stored on the device. The **blkid** program is used to read data from the device and obtain a unique identifier (that is, the uuid) for the device. For example:

```
UUID=3e6be9de-8139-11d1-9106-a43f08d823a6
```

/dev/disk/by-id

Entries in this directory provide a symbolic name that refers to the storage device by a unique identifier (different from all other storage devices). The identifier is a property of the device but is not stored in the contents (that is, the data) on the devices. For example:

```
/dev/disk/by-id/scsi-3600508e000000000ce506dc50ab0ad05
```

```
/dev/disk/by-id/wwn-0x600508e000000000ce506dc50ab0ad05
```

The id is obtained from the world-wide ID of the device, or the device serial number. The **/dev/disk/by-id** entries may also include a partition number. For example:

```
/dev/disk/by-id/scsi-3600508e000000000ce506dc50ab0ad05-part1
```

```
/dev/disk/by-id/wwn-0x600508e000000000ce506dc50ab0ad05-part1
```

/dev/disk/by-path

Entries in this directory provide a symbolic name that refers to the storage device by the hardware path used to access the device, beginning with a reference to the storage controller in the PCI hierachy, and including the SCSI host, channel, target, and LUN numbers and, optionally, the partition number. Although these names are preferable to using major and minor numbers or **sd** names, caution must be used to ensure that the target numbers do not change in a Fibre Channel SAN environment (for example, through

the use of persistent binding) and that the use of the names is updated if a host adapter is moved to a different PCI slot. In addition, there is the possibility that the SCSI host numbers could change if a HBA fails to probe, if drivers are loaded in a different order, or if a new HBA is installed on the system. An example of by-path listing is:

```
/dev/disk/by-path/pci-0000:03:00.0-scsi-0:1:0:0
```

The **/dev/disk/by-path** entries may also include a partition number, such as:

```
/dev/disk/by-path/pci-0000:03:00.0-scsi-0:1:0:0-part1
```

25.7.3.1. Limitations of the udev Device Naming Convention

The following are some limitations of the **udev** naming convention.

- It is possible that the device may not be accessible at the time the query is performed because the **udev** mechanism may rely on the ability to query the storage device when the **udev** rules are processed for a **udev** event. This is more likely to occur with Fibre Channel, iSCSI or FCoE storage devices when the device is not located in the server chassis.
- The kernel may also send **udev** events at any time, causing the rules to be processed and possibly causing the **/dev/disk/by-*** links to be removed if the device is not accessible.
- There can be a delay between when the **udev** event is generated and when it is processed (such as when a large number of devices are detected and the user-space **udevd** daemon takes some amount of time to process the rules for each one). This could cause a delay between when the kernel detects the device and when the **/dev/disk/by-*** names are available.
- External programs such as **blkid** invoked by the rules may open the device for a brief period of time, making the device inaccessible for other uses.

25.8. Removing a Storage Device

Before removing access to the storage device itself, it is advisable to back up data from the device first. Afterwards, flush I/O and remove all operating system references to the device (as described below). If the device uses multipathing, then do this for the multipath "pseudo device" (Section 25.7.2, “WWID”) and each of the identifiers that represent a path to the device. If you are only removing a path to a multipath device, and other paths will remain, then the procedure is simpler, as described in Section 25.10, “Adding a Storage Device or Path”.

Removal of a storage device is not recommended when the system is under memory pressure, since the I/O flush will add to the load. To determine the level of memory pressure, run the command **vmstat 1 100**; device removal is not recommended if:

- Free memory is less than 5% of the total memory in more than 10 samples per 100 (the command **free** can also be used to display the total memory).
- Swapping is active (non-zero **si** and **so** columns in the **vmstat** output).

The general procedure for removing all access to a device is as follows:

Procedure 25.9. Ensuring a Clean Device Removal

1. Close all users of the device and backup device data as needed.
2. Use **umount** to unmount any file systems that mounted the device.

3. Remove the device from any **md** and LVM volume using it. If the device is a member of an LVM Volume group, then it may be necessary to move data off the device using the **pvmove** command, then use the **vgreduce** command to remove the physical volume, and (optionally) **pvremove** to remove the LVM metadata from the disk.

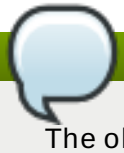
4. If the device uses multipathing, run **multipath -l** and note all the paths to the device. Afterwards, remove the multipathed device using **multipath -f device**.

5. Run **blockdev --flushbufs *device*** to flush any outstanding I/O to all paths to the device. This is particularly important for raw devices, where there is no **umount** or **vgreduce** operation to cause an I/O flush.

6. Remove any reference to the device's path-based name, like **/dev/sd**, **/dev/disk/by-path** or the **major:minor** number, in applications, scripts, or utilities on the system. This is important in ensuring that different devices added in the future will not be mistaken for the current device.

7. Finally, remove each path to the device from the SCSI subsystem. To do so, use the command **echo 1 > /sys/block/*device-name*/device/delete** where ***device-name*** may be **sde**, for example.

   Another variation of this operation is **echo 1 > /sys/class/scsi_device/*h*:*c*:*t*:*l*/device/delete**, where ***h*** is the HBA number, ***c*** is the channel on the HBA, ***t*** is the SCSI target ID, and ***l*** is the LUN.



Note

The older form of these commands, **echo "scsi remove-single-device 0 0 0 0" > /proc/scsi/scsi**, is deprecated.

You can determine the ***device-name***, HBA number, HBA channel, SCSI target ID and LUN for a device from various commands, such as **lsscsi**, **scsi_id**, **multipath -l**, and **ls -l /dev/disk/by-***.

After performing Procedure 25.9, “Ensuring a Clean Device Removal”, a device can be physically removed safely from a running system. It is not necessary to stop I/O to other devices while doing so.

Other procedures, such as the physical removal of the device, followed by a rescan of the SCSI bus (as described in Section 25.11, “Scanning Storage Interconnects”) to cause the operating system state to be updated to reflect the change, are not recommended. This will cause delays due to I/O timeouts, and devices may be removed unexpectedly. If it is necessary to perform a rescan of an interconnect, it must be done while I/O is paused, as described in Section 25.11, “Scanning Storage Interconnects”.

25.9. Removing a Path to a Storage Device

If you are removing a path to a device that uses multipathing (without affecting other paths to the device), then the general procedure is as follows:

Procedure 25.10. Removing a Path to a Storage Device

1. Remove any reference to the device's path-based name, like **/dev/sd** or **/dev/disk/by-path** or the **major:minor** number, in applications, scripts, or utilities on the system. This is important in ensuring that different devices added in the future will not be mistaken for the current device.

2. Take the path offline using **echo offline > /sys/block/sda/device/state**.

   This will cause any subsequent I/O sent to the device on this path to be failed immediately. **Device-mapper-multipath** will continue to use the remaining paths to the device.

3. Remove the path from the SCSI subsystem. To do so, use the command **echo 1 > /sys/block/*device-name*/device/delete** where ***device-name*** may be **sde**, for example (as described in Procedure 25.9, “Ensuring a Clean Device Removal”).

After performing Procedure 25.10, “Removing a Path to a Storage Device”, the path can be safely removed from the running system. It is not necessary to stop I/O while this is done, as **device-mapper-multipath** will re-route I/O to remaining paths according to the configured path grouping and failover policies.

Other procedures, such as the physical removal of the cable, followed by a rescan of the SCSI bus to cause the operating system state to be updated to reflect the change, are not recommended. This will cause delays due to I/O timeouts, and devices may be removed unexpectedly. If it is necessary to perform a rescan of an interconnect, it must be done while I/O is paused, as described in Section 25.11, “Scanning Storage Interconnects”.

25.10. Adding a Storage Device or Path

When adding a device, be aware that the path-based device name (**/dev/sd** name, **major:minor** number, and **/dev/disk/by-path** name, for example) the system assigns to the new device may have been previously in use by a device that has since been removed. As such, ensure that all old references to the path-based device name have been removed. Otherwise, the new device may be mistaken for the old device.

Procedure 25.11. Add a storage device or path

1. The first step in adding a storage device or path is to physically enable access to the new storage device, or a new path to an existing device. This is done using vendor-specific commands at the Fibre Channel or iSCSI storage server. When doing so, note the LUN value for the new storage that will be presented to your host. If the storage server is Fibre Channel, also take note of the *World Wide Node Name* (WWNN) of the storage server, and determine whether there is a single WWNN for all ports on the storage server. If this is not the case, note the *World Wide Port Name* (WWPN) for each port that will be used to access the new LUN.

2. Next, make the operating system aware of the new storage device, or path to an existing device. The recommended command to use is:

   ```
   $ echo "c t l" >  /sys/class/scsi_host/hosth/scan
   ```

   In the previous command, ***h*** is the HBA number, ***c*** is the channel on the HBA, ***t*** is the SCSI target ID, and ***l*** is the LUN.

   Note

   The older form of this command, **echo "scsi add-single-device 0 0 0 0" > /proc/scsi/scsi**, is deprecated.

a. In some Fibre Channel hardware, a newly created LUN on the RAID array may not be visible to the operating system until a *Loop Initialization Protocol* (LIP) operation is performed. Refer to Section 25.11, “Scanning Storage Interconnects” for instructions on how to do this.

Important

It will be necessary to stop I/O while this operation is executed if an LIP is required.

b. If a new LUN has been added on the RAID array but is still not being configured by the operating system, confirm the list of LUNs being exported by the array using the **sg_luns** command, part of the *sg3_utils* package. This will issue the **SCSI REPORT LUNS** command to the RAID array and return a list of LUNs that are present.

For Fibre Channel storage servers that implement a single WWNN for all ports, you can determine the correct ***h***,***c***,and ***t*** values (i.e. HBA number, HBA channel, and SCSI target ID) by searching for the WWNN in **sysfs**.

Example 25.5. Determin correct h, c, and t values

For example, if the WWNN of the storage server is **0x5006016090203181**, use:

```
$ grep 5006016090203181 /sys/class/fc_transport/*/node_name
```

This should display output similar to the following:

```
/sys/class/fc_transport/target5:0:2/node_name:0x5006016090203181
/sys/class/fc_transport/target5:0:3/node_name:0x5006016090203181
/sys/class/fc_transport/target6:0:2/node_name:0x5006016090203181
/sys/class/fc_transport/target6:0:3/node_name:0x5006016090203181
```

This indicates there are four Fibre Channel routes to this target (two single-channel HBAs, each leading to two storage ports). Assuming a LUN value is **56**, then the following command will configure the first path:

```
$ echo "0 2 56" >  /sys/class/scsi_host/host5/scan
```

This must be done for each path to the new device.

For Fibre Channel storage servers that do not implement a single WWNN for all ports, you can determine the correct HBA number, HBA channel, and SCSI target ID by searching for each of the WWPNs in **sysfs**.

Another way to determine the HBA number, HBA channel, and SCSI target ID is to refer to another device that is already configured on the same path as the new device. This can be done with various commands, such as **lsscsi**, **scsi_id**, **multipath -l**, and **ls -l /dev/disk/by-***. This information, plus the LUN number of the new device, can be used as shown above to probe and configure that path to the new device.

3. After adding all the SCSI paths to the device, execute the **multipath** command, and check to see that the device has been properly configured. At this point, the device can be added to **md**, LVM, **mkfs**, or **mount**, for example.

If the steps above are followed, then a device can safely be added to a running system. It is not necessary to stop I/O to other devices while this is done. Other procedures involving a rescan (or a reset) of the SCSI bus, which cause the operating system to update its state to reflect the current device connectivity, are not recommended while storage I/O is in progress.

25.11. Scanning Storage Interconnects

Certain commands allow you to reset, scan, or both reset and scan one or more interconnects, which potentially adds and removes multiple devices in one operation. This type of scan can be disruptive, as it can cause delays while I/O operations time out, and remove devices unexpectedly. Red Hat recommends using interconnect scanning *only when necessary*. Observe the following restrictions when scanning storage interconnects:

- All I/O on the effected interconnects must be paused and flushed before executing the procedure, and the results of the scan checked before I/O is resumed.
- As with removing a device, interconnect scanning is not recommended when the system is under memory pressure. To determine the level of memory pressure, run the **vmstat 1 100** command. Interconnect scanning is not recommended if free memory is less than 5% of the total memory in more than 10 samples per 100. Also, interconnect scanning is not recommended if swapping is active (non-zero **si** and **so** columns in the **vmstat** output). The **free** command can also display the total memory.

The following commands can be used to scan storage interconnects:

echo "1" > /sys/class/fc_host/host/issue_lip

This operation performs a *Loop Initialization Protocol* (*LIP*), scans the interconnect, and causes the SCSI layer to be updated to reflect the devices currently on the bus. Essentially, an LIP is a bus reset, and causes device addition and removal. This procedure is necessary to configure a new SCSI target on a Fibre Channel interconnect.

Note that **issue_lip** is an asynchronous operation. The command can complete before the entire scan has completed. You must monitor **/var/log/messages** to determine when **issue_lip** finishes.

The **lpfc**, **qla2xxx**, and **bnx2fc** drivers support **issue_lip**. For more information about the API capabilities supported by each driver in Red Hat Enterprise Linux, see Table 25.1, “Fibre Channel API Capabilities”.

/usr/bin/rescan-scsi-bus.sh

The **/usr/bin/rescan-scsi-bus.sh** script was introduced in Red Hat Enterprise Linux 5.4. By default, this script scans all the SCSI buses on the system, and updates the SCSI layer to reflect new devices on the bus. The script provides additional options to allow device removal, and the issuing of LIPs. For more information about this script, including known issues, see Section 25.17, “Adding/Removing a Logical Unit Through rescan-scsi-bus.sh”.

echo "- - -" > /sys/class/scsi_host/host*h*/scan

This is the same command as described in Section 25.10, “Adding a Storage Device or Path” to add a storage device or path. In this case, however, the channel number, SCSI target ID, and LUN values are replaced by wildcards. Any combination of identifiers and

wildcards is allowed, so you can make the command as specific or broad as needed. This procedure adds LUNs, but does not remove them.

modprobe --remove *driver-name*, modprobe *driver-name*

Running the **modprobe --remove *driver-name*** command followed by the **modprobe *driver-name*** command completely re-initializes the state of all interconnects controlled by the driver. Despite being rather extreme, using the described commands can be appropriate in certain situations. The commands can be used, for example, to restart the driver with a different module parameter value.

25.12. iSCSI Discovery Configuration

The default iSCSI configuration file is **/etc/iscsi/iscsid.conf**. This file contains iSCSI settings used by **iscsid** and **iscsiadm**.

During target discovery, the **iscsiadm** tool uses the settings in **/etc/iscsi/iscsid.conf** to create two types of records:

Node records in /var/lib/iscsi/nodes

When logging into a target, **iscsiadm** uses the settings in this file.

Discovery records in /var/lib/iscsi/*discovery_type*

When performing discovery to the same destination, **iscsiadm** uses the settings in this file.

Before using different settings for discovery, delete the current discovery records (i.e. **/var/lib/iscsi/*discovery_type***) first. To do this, use the following command:

iscsiadm -m discovery -t *discovery_type* -p *target_IP*:*port* -o delete [5]

Here, ***discovery_type*** can be either **sendtargets**, **isns**, or **fw**.

For details on different types of discovery, refer to the *DISCOVERY TYPES* section of **man iscsiadm**.

There are two ways to reconfigure discovery record settings:

- Edit the **/etc/iscsi/iscsid.conf** file directly prior to performing a discovery. Discovery settings use the prefix **discovery**; to view them, run:

```
# iscsiadm -m discovery -t discovery_type -p target_IP:port
```

- Alternatively, **iscsiadm** can also be used to directly change discovery record settings, as in:

```
# iscsiadm -m discovery -t discovery_type -p target_IP:port -o update
-n setting -v %value
```

Refer to **man iscsiadm** for more information on available ***setting***s and valid ***value***s for each.

After configuring discovery settings, any subsequent attempts to discover new targets will use the new settings. Refer to Section 25.14, “Scanning iSCSI Interconnects” for details on how to scan for new iSCSI targets.

For more information on configuring iSCSI target discovery, refer to the **man** pages of **iscsiadm** and **iscsid**. The **/etc/iscsi/iscsid.conf** file also contains examples on proper configuration syntax.

25.13. Configuring iSCSI Offload and Interface Binding

This chapter describes how to set up iSCSI interfaces in order to bind a session to a NIC port when using software iSCSI. It also describes how to set up interfaces for use with network devices that support offloading.

The network subsystem can be configured to determine the path/NIC that iSCSI interfaces should use for binding. For example, if portals and NICs are set up on different subnets, then it is not necessary to manually configure iSCSI interfaces for binding.

Before attempting to configure an iSCSI interface for binding, run the following command first:

```
$ ping -I ethX target_IP
```

If **ping** fails, then you will not be able to bind a session to a NIC. If this is the case, check the network settings first.

25.13.1. Viewing Available iface Configurations

iSCSI offload and interface binding is supported for the following iSCSI initiator implementations:

Software iSCSI

This stack allocates an iSCSI host instance (that is, **scsi_host**) per session, with a single connection per session. As a result, **/sys/class_scsi_host** and **/proc/scsi** will report a **scsi_host** for each connection/session you are logged into.

Offload iSCSI

This stack allocates a **scsi_host** for each PCI device. As such, each port on a host bus adapter will show up as a different PCI device, withh a different **scsi_host** per HBA port.

To manage both types of initiator implementations, **iscsiadm** uses the **iface** structure. With this structure, an **iface** configuration must be entered in **/var/lib/iscsi/ifaces** for each HBA port, software iSCSI, or network device (**ethX**) used to bind sessions.

To view available **iface** configurations, run **iscsiadm -m iface**. This will display **iface** information in the following format:

```
iface_name
transport_name,hardware_address,ip_address,net_ifacename,initiator_name
```

Refer to the following table for an explanation of each value/setting.

Table 25.2. iface Settings

Setting	Description
iface_name	**iface** configuration name.
transport_name	Name of driver
hardware_address	MAC address
ip_address	IP address to use for this port
net_iface_name	Name used for the **vlan** or alias binding of a software iSCSI session. For iSCSI offloads, **net_iface_name** will be **<empty>** because this value is not persistent across reboots.

Setting	Description
initiator_name	This setting is used to override a default name for the initiator, which is defined in **/etc/iscsi/initiatorname.iscsi**

Example 25.6. Sample output of the iscsiadm -m iface command

The following is a sample output of the **iscsiadm -m iface** command:

```
iface0 qla4xxx,00:c0:dd:08:63:e8,20.15.0.7,default,iqn.2005-
06.com.redhat:madmax
iface1 qla4xxx,00:c0:dd:08:63:ea,20.15.0.9,default,iqn.2005-
06.com.redhat:madmax
```

For software iSCSI, each **iface** configuration must have a unique name (with less than 65 characters). The **iface_name** for network devices that support offloading appears in the format ***transport_name*.*hardware_name***.

Example 25.7. iscsiadm -m iface output with a Chelsio network card

For example, the sample output of **iscsiadm -m iface** on a system using a Chelsio network card might appear as:

```
default tcp,<empty>,<empty>,<empty>,<empty>
iser iser,<empty>,<empty>,<empty>,<empty>
cxgb3i.00:07:43:05:97:07 cxgb3i,00:07:43:05:97:07,<empty>,<empty>,
<empty>
```

It is also possible to display the settings of a specific **iface** configuration in a more friendly way. To do so, use the option **-I *iface_name***. This will display the settings in the following format:

```
iface.setting = value
```

Example 25.8. Using iface settings with a Chelsio converged network adapter

Using the previous example, the **iface** settings of the same Chelsio converged network adapter (i.e. **iscsiadm -m iface -I cxgb3i.00:07:43:05:97:07**) would appear as:

```
# BEGIN RECORD 2.0-871
iface.iscsi_ifacename = cxgb3i.00:07:43:05:97:07
iface.net_ifacename = <empty>
iface.ipaddress = <empty>
iface.hwaddress = 00:07:43:05:97:07
iface.transport_name = cxgb3i
iface.initiatorname = <empty>
# END RECORD
```

25.13.2. Configuring an iface for Software iSCSI

As mentioned earlier, an **iface** configuration is required for each network object that will be used to bind a session.

Before

To create an **iface** configuration for software iSCSI, run the following command:

```
# iscsiadm -m iface -I iface_name --op=new
```

This will create a new *empty* **iface** configuration with a specified ***iface_name***. If an existing **iface** configuration already has the same ***iface_name***, then it will be overwritten with a new, empty one.

To configure a specific setting of an **iface** configuration, use the following command:

```
# iscsiadm -m iface -I iface_name --op=update -n iface.setting -v
hw_address
```

Example 25.9. Set MAC address of iface0

For example, to set the MAC address (**hardware_address**) of **iface0** to **00:0F:1F:92:6B:BF**, run:

```
# iscsiadm -m iface -I iface0 --op=update -n iface.hwaddress -v
00:0F:1F:92:6B:BF
```

Warning

Do not use **default** or **iser** as **iface** names. Both strings are special values used by **iscsiadm** for backward compatibility. Any manually-created **iface** configurations named **default** or **iser** will disable backwards compatibility.

25.13.3. Configuring an iface for iSCSI Offload

By default **iscsiadm** will create an **iface** configuration for each port. To view available **iface** configurations, use the same command for doing so in software iSCSI, i.e. **iscsiadm -m iface**.

Before using the **iface** of a network card for iSCSI offload, first set the IP address (***target_IP***[5]) that the device should use. For devices that use the **be2iscsi** driver, the IP address is configured in the BIOS setup screen. For all other devices, to configure the IP address of the **iface** use:

```
# iscsiadm -m iface -I iface_name -o update -n iface.ipaddress -v
target_IP
```

Example 25.10. Set the iface IP address of a Chelsio card

For example, to set the **iface** IP address to **20.15.0.66** when using a card with the iface name of cxgb3i.00:07:43:05:97:07, use:

```
# iscsiadm -m iface -I cxgb3i.00:07:43:05:97:07 -o update -n
iface.ipaddress -v 20.15.0.66
```

25.13.4. Binding/Unbinding an iface to a Portal

Whenever **iscsiadm** is used to scan for interconnects, it will first check the **iface.transport** settings of each **iface** configuration in **/var/lib/iscsi/ifaces**. The **iscsiadm** utility will then bind discovered portals to any **iface** whose **iface.transport** is **tcp**.

This behavior was implemented for compatibility reasons. To override this, use the **-I *iface_name*** to specify which portal to bind to an **iface**, as in:

```
# iscsiadm -m discovery -t st -p target_IP:port -I iface_name -P 1
[5]
```

By default, the **iscsiadm** utility will not automatically bind any portals to **iface** configurations that use offloading. This is because such **iface** configurations will not have **iface.transport** set to **tcp**. As such, the **iface** configurations need to be manually bound to discovered portals.

It is also possible to prevent a portal from binding to any existing **iface**. To do so, use **default** as the ***iface_name***, as in:

```
# iscsiadm -m discovery -t st -p IP:port -I default -P 1
```

To remove the binding between a target and **iface**, use:

```
# iscsiadm -m node -targetname proper_target_name -I iface0 --op=delete
      [6]
```

To delete all bindings for a specific **iface**, use:

```
# iscsiadm -m node -I iface_name --op=delete
```

To delete bindings for a specific portal (e.g. for Equalogic targets), use:

```
# iscsiadm -m node -p IP:port -I iface_name --op=delete
```

Note

If there are no **iface** configurations defined in **/var/lib/iscsi/iface** and the **-I** option is not used, **iscsiadm** will allow the network subsystem to decide which device a specific portal should use.

25.14. Scanning iSCSI Interconnects

For iSCSI, if the targets send an iSCSI async event indicating new storage is added, then the scan is done automatically.

However, if the targets do not send an iSCSI async event, you need to manually scan them using the **iscsiadm** utility. Before doing so, however, you need to first retrieve the proper **--targetname** and the **--portal** values. If your device model supports only a single logical unit and portal per target, use **iscsiadm** to issue a **sendtargets** command to the host, as in:

```
# iscsiadm -m discovery -t sendtargets -p target_IP:port
[5]
```

The output will appear in the following format:

```
target_IP:port,target_portal_group_tag proper_target_name
```

Example 25.11. Using iscsiadm to issue a sendtargets command

For example, on a target with a ***proper_target_name*** of **iqn.1992-08.com.netapp:sn.33615311** and a ***target_IP:port*** of **10.15.85.19:3260**, the output may appear as:

```
10.15.84.19:3260,2 iqn.1992-08.com.netapp:sn.33615311
10.15.85.19:3260,3 iqn.1992-08.com.netapp:sn.33615311
```

In this example, the target has two portals, each using ***target_ip:port***s of **10.15.84.19:3260** and **10.15.85.19:3260**.

To see which **iface** configuration will be used for each session, add the **-P 1** option. This option will print also session information in tree format, as in:

```
    Target: proper_target_name
        Portal: target_IP:port,target_portal_group_tag
           Iface Name: iface_name
```

Example 25.12. View iface configuration

For example, with **iscsiadm -m discovery -t sendtargets -p 10.15.85.19:3260 -P 1**, the output may appear as:

```
Target: iqn.1992-08.com.netapp:sn.33615311
    Portal: 10.15.84.19:3260,2
       Iface Name: iface2
    Portal: 10.15.85.19:3260,3
       Iface Name: iface2
```

This means that the target **iqn.1992-08.com.netapp:sn.33615311** will use **iface2** as its **iface** configuration.

With some device models a single target may have multiple logical units and portals. In this case, issue a **sendtargets** command to the host first to find new portals on the target. Then, rescan the existing sessions using:

```
# iscsiadm -m session --rescan
```

You can also rescan a specific session by specifying the session's ***SID*** value, as in:

```
# iscsiadm -m session -r SID --rescan
      [7]
```

If your device supports multiple targets, you will need to issue a **sendtargets** command to the hosts to find new portals for *each* target. Rescan existing sessions to discover new logical units on existing sessions using the **--rescan** option.

Important

The **sendtargets** command used to retrieve **--targetname** and **--portal** values overwrites the contents of the **/var/lib/iscsi/nodes** database. This database will then be repopulated using the settings in **/etc/iscsi/iscsid.conf**. However, this will not occur if a session is currently logged in and in use.

To safely add new targets/portals or delete old ones, use the **-o new** or **-o delete** options, respectively. For example, to add new targets/portals without overwriting **/var/lib/iscsi/nodes**, use the following command:

```
iscsiadm -m discovery -t st -p target_IP -o new
```

To delete **/var/lib/iscsi/nodes** entries that the target did not display during discovery, use:

```
iscsiadm -m discovery -t st -p target_IP -o delete
```

You can also perform both tasks simultaneously, as in:

```
iscsiadm -m discovery -t st -p target_IP -o delete -o new
```

The **sendtargets** command will yield the following output:

```
ip:port,target_portal_group_tag proper_target_name
```

Example 25.13. Output of the sendtargets command

For example, given a device with a single target, logical unit, and portal, with **equallogic-iscsi1** as your ***target_name***, the output should appear similar to the following:

```
10.16.41.155:3260,0 iqn.2001-05.com.equallogic:6-8a0900-ac3fe0101-
63aff113e344a4a2-dl585-03-1
```

Note that ***proper_target_name*** and ***ip:port,target_portal_group_tag*** are identical to the values of the same name in Section 25.6.1, “iSCSI API”.

At this point, you now have the proper **--targetname** and **--portal** values needed to manually scan for iSCSI devices. To do so, run the following command:

```
# iscsiadm --mode node --targetname proper_target_name --portal
ip:port,target_portal_group_tag \ --login

      [8]
```

Example 25.14. Full iscsiadm command

Using our previous example (where ***proper_target_name*** is **equallogic-iscsi1**), the full command would be:

```
# iscsiadm --mode node --targetname  \ iqn.2001-05.com.equallogic:6-
8a0900-ac3fe0101-63aff113e344a4a2-dl585-03-1  \ --portal
10.16.41.155:3260,0 --login[8]
```

25.15. Logging in to an iSCSI Target

As mentioned in Section 25.6, “iSCSI”, the iSCSI service must be running in order to discover or log into targets. To start the iSCSI service, run:

```
# service iscsi start
```

When this command is executed, the iSCSI **init** scripts will automatically log into targets where the **node.startup** setting is configured as **automatic**. This is the default value of **node.startup** for all targets.

To prevent automatic login to a target, set **node.startup** to **manual**. To do this, run the following command:

```
# iscsiadm -m node --targetname proper_target_name -p target_IP:port -o
update -n node.startup -v manual
```

Deleting the entire record will also prevent automatic login. To do this, run:

```
# iscsiadm -m node --targetname proper_target_name -p target_IP:port -o
delete
```

To automatically mount a file system from an iSCSI device on the network, add a partition entry for the mount in **/etc/fstab** with the **_netdev** option. For example, to automatically mount the iSCSI device **sdb** to **/mount/iscsi** during startup, add the following line to **/etc/fstab**:

```
/dev/sdb /mnt/iscsi ext3 _netdev 0 0
```

To manually log in to an iSCSI target, use the following command:

```
# iscsiadm -m node --targetname proper_target_name -p target_IP:port -l
```

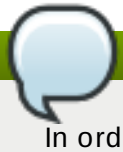
Note

The ***proper_target_name*** and ***target_IP:port*** refer to the full name and IP address/port combination of a target. For more information, refer to Section 25.6.1, “iSCSI API” and Section 25.14, “Scanning iSCSI Interconnects”.

25.16. Resizing an Online Logical Unit

In most cases, fully resizing an online *logical unit* involves two things: resizing the logical unit itself and reflecting the size change in the corresponding multipath device (if multipathing is enabled on the system).

To resize the online logical unit, start by modifying the logical unit size through the array management interface of your storage device. This procedure differs with each array; as such, consult your storage array vendor documentation for more information on this.



Note

In order to resize an online file system, the file system must not reside on a partitioned device.

25.16.1. Resizing Fibre Channel Logical Units

After modifying the online logical unit size, re-scan the logical unit to ensure that the system detects the updated size. To do this for Fibre Channel logical units, use the following command:

```
$ echo 1 > /sys/block/sdX/device/rescan
```

Important

To re-scan Fibre Channel logical units on a system that uses multipathing, execute the aforementioned command for each sd device (i.e. **sd1**, **sd2**, and so on) that represents a path for the multipathed logical unit. To determine which devices are paths for a multipath logical unit, use **multipath -ll**; then, find the entry that matches the logical unit being resized. It is advisable that you refer to the WWID of each entry to make it easier to find which one matches the logical unit being resized.

25.16.2. Resizing an iSCSI Logical Unit

After modifying the online logical unit size, re-scan the logical unit to ensure that the system detects the updated size. To do this for iSCSI devices, use the following command:

```
# iscsiadm -m node --targetname target_name -R
[5]
```

Replace ***target_name*** with the name of the target where the device is located.

Note

You can also re-scan iSCSI logical units using the following command:

```
# iscsiadm -m node -R -I interface
```

Replace ***interface*** with the corresponding interface name of the resized logical unit (for example, **iface0**). This command performs two operations:

- It scans for new devices in the same way that the command **echo "- - -" > /sys/class/scsi_host/*host*/scan** does (refer to Section 25.14, "Scanning iSCSI Interconnects").
- It re-scans for new/modified logical units the same way that the command **echo 1 > /sys/block/sdX/device/rescan** does. Note that this command is the same one used for re-scanning Fibre Channel logical units.

25.16.3. Updating the Size of Your Multipath Device

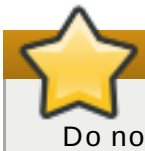
If multipathing is enabled on your system, you will also need to reflect the change in logical unit size to the logical unit's corresponding multipath device (*after* resizing the logical unit). This can be done through **multipathd**. To do so, first ensure that **multipathd** is running using **service multipathd status**. Once you've verified that **multipathd** is operational, run the following command:

```
# multipathd -k"resize map multipath_device"
```

The ***multipath_device*** variable is the corresponding multipath entry of your device in **/dev/mapper**. Depending on how multipathing is set up on your system, ***multipath_device*** can be either of two formats:

- **mpath*X***, where ***X*** is the corresponding entry of your device (for example, **mpath0**)
- a WWID; for example, **3600508b400105e21000090000000490000**

To determine which multipath entry corresponds to your resized logical unit, run **multipath -ll**. This displays a list of all existing multipath entries in the system, along with the major and minor numbers of their corresponding devices.



Important

Do not use **multipathd -k"resize map *multipath_device*"** if there are any commands queued to ***multipath_device***. That is, do not use this command when the **no_path_retry** parameter (in **/etc/multipath.conf**) is set to **"queue"**, and there are no active paths to the device.

For more information about multipathing, refer to the *Red Hat Enterprise Linux 7 DM Multipath* guide.

25.16.4. Changing the Read/Write State of an Online Logical Unit

Certain storage devices provide the user with the ability to change the state of the device from

Read/Write (R/W) to Read-Only (RO), and from RO to R/W. This is typically done through a management interface on the storage device. The operating system will not automatically update its view of the state of the device when a change is made. Follow the procedures described in this chapter to make the operating system aware of the change.

Run the following command, replacing XYZ with the desired device designator, to determine the operating system's current view of the R/W state of a device:

```
# blockdev --getro /dev/sdXYZ
```

The following command is also available for Red Hat Enterprise Linux 7:

```
# cat /sys/block/sdXYZ/ro 1 = read-only 0 = read-write
```

When using multipath, refer to the *ro* or *rw* field in the second line of output from the **multipath -ll** command. For example:

```
36001438005deb47100000500000640000 dm-8 GZ,GZ500
[size=20G][features=0][hwhandler=0][ro]
\_ round-robin 0 [prio=200][active]
 \_ 6:0:4:1  sdax 67:16  [active][ready]
 \_ 6:0:5:1  sday 67:32  [active][ready]
\_ round-robin 0 [prio=40][enabled]
 \_ 6:0:6:1  sdaz 67:48  [active][ready]
 \_ 6:0:7:1  sdba 67:64  [active][ready]
```

To change the R/W state, use the following procedure:

Procedure 25.12. Change the R/W state

1. To move the device from RO to R/W, see step 2.

   To move the device from R/W to RO, ensure no further writes will be issued. Do this by stopping the application, or through the use of an appropriate, application-specific action.

   Ensure that all outstanding write I/Os are complete with the following command:

   ```
   # blockdev --flushbufs /dev/device
   ```

   Replace *device* with the desired designator; for a device mapper multipath, this is the entry for your device in **dev/mapper**. For example, **/dev/mapper/mpath3**.

2. Use the management interface of the storage device to change the state of the logical unit from R/W to RO, or from RO to R/W. The procedure for this differs with each array. Consult applicable storage array vendor documentation for more information.

3. Perform a re-scan of the device to update the operating system's view of the R/W state of the device. If using a device mapper multipath, perform this re-scan for each path to the device before issuing the command telling multipath to reload its device maps.

   This process is explained in further detail in Section 25.16.4.1, “Rescanning logical units”.

25.16.4.1. Rescanning logical units

After modifying the online logical unit Read/Write state, as described in Section 25.16.4, "Changing the Read/Write State of an Online Logical Unit", re-scan the logical unit to ensure the system detects the updated state with the following command:

```
# echo 1 > /sys/block/sdX/device/rescan
```

To re-scan logical units on a system that uses multipathing, execute the above command for each sd device that represents a path for the multipathed logical unit. For example, run the command on sd1, sd2 and all other sd devices. To determine which devices are paths for a multipath unit, use **multipath -11**, then find the entry that matches the logical unit to be changed.

Example 25.15. Use of the multipath -11 command

For example, the **multipath -11** above shows the path for the LUN with WWID 36001438005deb4710000500000640000. In this case, enter:

```
# echo 1 > /sys/block/sdax/device/rescan
# echo 1 > /sys/block/sday/device/rescan
# echo 1 > /sys/block/sdaz/device/rescan
# echo 1 > /sys/block/sdba/device/rescan
```

25.16.4.2. Updating the R/W state of a multipath device

If multipathing is enabled, after rescanning the logical unit, the change in its state will need to be reflected in the logical unit's corresponding multipath drive. Do this by reloading the multipath device maps with the following command:

```
# multipath -r
```

The **multipath -11** command can then be used to confirm the change.

25.16.4.3. Documentation

Further information can be found in the Red Hat Knowledgebase. To access this, navigate to https://www.redhat.com/wapps/sso/login.html?redirect=https://access.redhat.com/knowledge/ and log in. Then access the article at https://access.redhat.com/kb/docs/DOC-32850.

25.17. Adding/Removing a Logical Unit Through rescan-scsi-bus.sh

The **sg3_utils** package provides the **rescan-scsi-bus.sh** script, which can automatically update the logical unit configuration of the host as needed (after a device has been added to the system). The **rescan-scsi-bus.sh** script can also perform an **issue_lip** on supported devices. For more information about how to use this script, refer to **rescan-scsi-bus.sh --help**.

To install the **sg3_utils** package, run **yum install sg3_utils**.

Known Issues With rescan-scsi-bus.sh

When using the **rescan-scsi-bus.sh** script, take note of the following known issues:

- In order for **rescan-scsi-bus.sh** to work properly, **LUN0** must be the first mapped logical unit. The **rescan-scsi-bus.sh** can only detect the first mapped logical unit if it is **LUN0**. The **rescan-scsi-bus.sh** will not be able to scan any other logical unit unless it detects the first mapped logical unit even if you use the **--nooptscan** option.
- A race condition requires that **rescan-scsi-bus.sh** be run twice if logical units are mapped for the first time. During the first scan, **rescan-scsi-bus.sh** only adds **LUN0**; all other logical units are added in the second scan.
- A bug in the **rescan-scsi-bus.sh** script incorrectly executes the functionality for recognizing a change in logical unit size when the **--remove** option is used.
- The **rescan-scsi-bus.sh** script does not recognize ISCSI logical unit removals.

25.18. Modifying Link Loss Behavior

This section describes how to modify the link loss behavior of devices that use either Fibre Channel or iSCSI protocols.

25.18.1. Fibre Channel

If a driver implements the Transport **dev_loss_tmo** callback, access attempts to a device through a link will be blocked when a transport problem is detected. To verify if a device is blocked, run the following command:

```
$ cat /sys/block/device/device/state
```

This command will return **blocked** if the device is blocked. If the device is operating normally, this command will return **running**.

Procedure 25.13. Determining The State of a Remote Port

1. To determine the state of a remote port, run the following command:

   ```
   $ cat
   /sys/class/fc_remote_port/rport-H:B:R/port_state
   ```

2. This command will return **Blocked** when the remote port (along with devices accessed through it) are blocked. If the remote port is operating normally, the command will return **Online**.

3. If the problem is not resolved within **dev_loss_tmo** seconds, the rport and devices will be unblocked and all I/O running on that device (along with any new I/O sent to that device) will be failed.

Procedure 25.14. Changing dev_loss_tmo

- To change the **dev_loss_tmo** value, **echo** in the desired value to the file. For example, to set **dev_loss_tmo** to 30 seconds, run:

  ```
  $ echo 30 >
  /sys/class/fc_remote_port/rport-H:B:R/dev_loss_tmo
  ```

For more information about **dev_loss_tmo**, refer to Section 25.3.1, “Fibre Channel API”.

When a link loss exceeds **dev_loss_tmo**, the **scsi_device** and **sd*N*** devices are removed. Typically, the Fibre Channel class will leave the device as is; i.e. **/dev/sd*x*** will remain **/dev/sd*x***. This is because the target binding is saved by the Fibre Channel driver so when the target port returns, the SCSI addresses are recreated faithfully. However, this cannot be guaranteed; the **sd*x*** will be restored only if no additional change on in-storage box configuration of LUNs is made.

25.18.2. iSCSI Settings With dm-multipath

If **dm-multipath** is implemented, it is advisable to set iSCSI timers to immediately defer commands to the multipath layer. To configure this, nest the following line under **device {** in **/etc/multipath.conf**:

```
features  "1 queue_if_no_path"
```

This ensures that I/O errors are retried and queued if all paths are failed in the **dm-multipath** layer.

You may need to adjust iSCSI timers further to better monitor your SAN for problems. Available iSCSI timers you can configure are *NOP-Out Interval/Timeouts* and **replacement_timeout**, which are discussed in the following sections.

25.18.2.1. NOP-Out Interval/Timeout

To help monitor problems the SAN, the iSCSI layer sends a NOP-Out request to each target. If a NOP-Out request times out, the iSCSI layer responds by failing any running commands and instructing the SCSI layer to requeue those commands when possible.

When **dm-multipath** is being used, the SCSI layer will fail those running commands and defer them to the multipath layer. The multipath layer then retries those commands on another path. If **dm-multipath** is *not* being used, those commands are retried five times before failing altogether.

Intervals between NOP-Out requests are 10 seconds by default. To adjust this, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.conn[0].timeo.noop_out_interval = [interval value]
```

Once set, the iSCSI layer will send a NOP-Out request to each target every *[interval value]* seconds.

By default, NOP-Out requests time out in 10 seconds [9]. To adjust this, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.conn[0].timeo.noop_out_timeout = [timeout value]
```

This sets the iSCSI layer to timeout a NOP-Out request after *[timeout value]* seconds.

SCSI Error Handler

If the SCSI Error Handler is running, running commands on a path will not be failed immediately when a NOP-Out request times out on that path. Instead, those commands will be failed *after* **replacement_timeout** seconds. For more information about **replacement_timeout**, refer to Section 25.18.2.2, “**replacement_timeout**”.

To verify if the SCSI Error Handler is running, run:

```
# iscsiadm -m session -P 3
```

25.18.2.2. replacement_timeout

replacement_timeout controls how long the iSCSI layer should wait for a timed-out path/session to reestablish itself before failing any commands on it. The default **replacement_timeout** value is 120 seconds.

To adjust **replacement_timeout**, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.session.timeo.replacement_timeout = [replacement_timeout]
```

The **1 queue_if_no_path** option in **/etc/multipath.conf** sets iSCSI timers to immediately defer commands to the multipath layer (refer to Section 25.18.2, "iSCSI Settings With **dm-multipath**"). This setting prevents I/O errors from propagating to the application; because of this, you can set **replacement_timeout** to 15-20 seconds.

By configuring a lower **replacement_timeout**, I/O is quickly sent to a new path and executed (in the event of a NOP-Out timeout) while the iSCSI layer attempts to re-establish the failed path/session. If all paths time out, then the multipath and device mapper layer will internally queue I/O based on the settings in **/etc/multipath.conf** instead of **/etc/iscsi/iscsid.conf**.

Important

Whether your considerations are failover speed or security, the recommended value for **replacement_timeout** will depend on other factors. These factors include the network, target, and system workload. As such, it is recommended that you thoroughly test any new configurations to **replacements_timeout** before applying it to a mission-critical system.

25.18.3. iSCSI Root

When accessing the root partition directly through an iSCSI disk, the iSCSI timers should be set so that iSCSI layer has several chances to try to reestablish a path/session. In addition, commands should not be quickly re-queued to the SCSI layer. This is the opposite of what should be done when **dm-multipath** is implemented.

To start with, NOP-Outs should be disabled. You can do this by setting both NOP-Out interval and timeout to zero. To set this, open **/etc/iscsi/iscsid.conf** and edit as follows:

```
node.conn[0].timeo.noop_out_interval = 0
node.conn[0].timeo.noop_out_timeout = 0
```

In line with this, **replacement_timeout** should be set to a high number. This will instruct the system to wait a long time for a path/session to reestablish itself. To adjust **replacement_timeout**, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.session.timeo.replacement_timeout = replacement_timeout
```

After configuring **/etc/iscsi/iscsid.conf**, you must perform a re-discovery of the affected storage. This will allow the system to load and use any new values in **/etc/iscsi/iscsid.conf**. For more information on how to discover iSCSI devices, refer to Section 25.14, "Scanning iSCSI Interconnects".

Configuring Timeouts for a Specific Session

You can also configure timeouts for a specific session and make them non-persistent (instead of using **/etc/iscsi/iscsid.conf**). To do so, run the following command (replace the variables accordingly):

```
# iscsiadm -m node -T target_name -p target_IP:port -o update -n
node.session.timeo.replacement_timeout -v $timeout_value
```

Important

The configuration described here is recommended for iSCSI sessions involving root partition access. For iSCSI sessions involving access to other types of storage (namely, in systems that use **dm-multipath**), refer to Section 25.18.2, “iSCSI Settings With **dm-multipath**”.

25.19. Controlling the SCSI Command Timer and Device Status

The Linux SCSI layer sets a timer on each command. When this timer expires, the SCSI layer will quiesce the *host bus adapter* (HBA) and wait for all outstanding commands to either time out or complete. Afterwards, the SCSI layer will activate the driver's error handler.

When the error handler is triggered, it attempts the following operations in order (until one successfully executes):

1. Abort the command.
2. Reset the device.
3. Reset the bus.
4. Reset the host.

If all of these operations fail, the device will be set to the **offline** state. When this occurs, all I/O to that device will be failed, until the problem is corrected and the user sets the device to **running**.

The process is different, however, if a device uses the Fibre Channel protocol and the **rport** is blocked. In such cases, the drivers wait for several seconds for the **rport** to become online again before activating the error handler. This prevents devices from becoming offline due to temporary transport problems.

Device States

To display the state of a device, use:

```
$ cat /sys/block/device-name/device/state
```

To set a device to **running** state, use:

```
$ echo running > /sys/block/device-name/device/state
```

Command Timer

To control the command timer, you can write to **/sys/block/*device-name*/device/timeout**. To do so, run:

echo *value* /sys/block/*device-name*/device/timeout

Here, ***value*** is the timeout value (in seconds) you want to implement.

25.20. Online Storage Configuration Troubleshooting

This section provides solution to common problems users experience during online storage reconfiguration.

Logical unit removal status is not reflected on the host.

When a logical unit is deleted on a configured filer, the change is not reflected on the host. In such cases, **lvm** commands will hang indefinitely when **dm-multipath** is used, as the logical unit has now become *stale*.

To work around this, perform the following procedure:

Procedure 25.15. Working Around Stale Logical Units

1. Determine which **mpath** link entries in **/etc/lvm/cache/.cache** are specific to the stale logical unit. To do this, run the following command:

```
$ ls -l /dev/mpath | grep stale-logical-unit
```

Example 25.16. Determine specific mpath link entries

For example, if ***stale-logical-unit*** is 3600d0230003414f30000203a7bc41a00, the following results may appear:

```
lrwxrwxrwx 1 root root 7 Aug  2 10:33
/3600d0230003414f30000203a7bc41a00 -> ../dm-4
lrwxrwxrwx 1 root root 7 Aug  2 10:33
/3600d0230003414f30000203a7bc41a00p1 -> ../dm-5
```

This means that 3600d0230003414f30000203a7bc41a00 is mapped to two **mpath** links: **dm-4** and **dm-5**.

2. Next, open **/etc/lvm/cache/.cache**. Delete all lines containing ***stale-logical-unit*** and the **mpath** links that ***stale-logical-unit*** maps to.

Example 25.17. Delete relevant lines

Using the same example in the previous step, the lines you need to delete are:

```
/dev/dm-4
/dev/dm-5
/dev/mapper/3600d0230003414f30000203a7bc41a00
/dev/mapper/3600d0230003414f30000203a7bc41a00p1
/dev/mpath/3600d0230003414f30000203a7bc41a00
/dev/mpath/3600d0230003414f30000203a7bc41a00p1
```

[5] The ***target_IP*** and ***port*** variables refer to the IP address and port combination of a target/portal, respectively. For more information, refer to Section 25.6.1, “iSCSI API” and Section 25.14, “Scanning iSCSI Interconnects”.

[6] Refer to Section 25.14, “Scanning iSCSI Interconnects” for information on ***proper_target_name***.

[7] For information on how to retrieve a session's SID value, refer to Section 25.6.1, “iSCSI API”.

[8] This is a single command split into multiple lines, to accommodate printed and PDF versions of this document. All concatenated lines — preceded by the backslash (\) — should be treated as one command, sans backslashes.

[9] Prior to Red Hat Enterprise Linux 5.4, the default NOP-Out requests time out was 15 seconds.

Chapter 26. Device Mapper Multipathing and Virtual Storage

Red Hat Enterprise Linux 7 supports *DM-Multipath* and *virtual storage*. Both features are documented in detail in the Red Hat books *DM Multipath* and *Virtualization Deployment and Administration Guide*.

26.1. Virtual Storage

Red Hat Enterprise Linux 7 supports the following file systems/online storage methods for virtual storage:

- Fibre Channel
- iSCSI
- NFS
- GFS2

Virtualization in Red Hat Enterprise Linux 7 uses **`libvirt`** to manage virtual instances. The **`libvirt`** utility uses the concept of *storage pools* to manage storage for virtualized guests. A storage pool is storage that can be divided up into smaller volumes or allocated directly to a guest. Volumes of a storage pool can be allocated to virtualized guests. There are two categories of storage pools available:

Local storage pools

Local storage covers storage devices, files or directories directly attached to a host. Local storage includes local directories, directly attached disks, and LVM Volume Groups.

Networked (shared) storage pools

Networked storage covers storage devices shared over a network using standard protocols. It includes shared storage devices using Fibre Channel, iSCSI, NFS, GFS2, and SCSI RDMA protocols, and is a requirement for migrating guest virtualized guests between hosts.

Important

For comprehensive information on the deployment and configuration of virtual storage instances in your environment, refer to the *Virtualization Deployment and Administration Guide* provided by Red Hat.

26.2. DM-Multipath

Device Mapper Multipathing (DM-Multipath) is a feature that allows you to configure multiple I/O paths between server nodes and storage arrays into a single device. These I/O paths are physical SAN connections that can include separate cables, switches, and controllers. Multipathing aggregates the I/O paths, creating a new device that consists of the aggregated paths.

DM-Multipath are used primarily for the following reasons:

Redundancy

DM-Multipath can provide failover in an active/passive configuration. In an active/passive configuration, only half the paths are used at any time for I/O. If any element of an I/O path

(the cable, switch, or controller) fails, DM-Multipath switches to an alternate path.

Improved Performance

DM-Multipath can be configured in active/active mode, where I/O is spread over the paths in a round-robin fashion. In some configurations, DM-Multipath can detect loading on the I/O paths and dynamically re-balance the load.

Important

For comprehensive information on the deployment and configuration of DM-Multipath in your environment, refer to the *Using DM-Multipath* guide provided by Red Hat.

Chapter 27. External Array Management (`libStorageMgmt`)

Red Hat Enterprise Linux 7 ships with a new external array management package called **`libStorageMgmt`**.

27.1. What is `libStorageMgmt`

The **`libStorageMgmt`** package is a storage array independent Application Programming Interface (API). It provides a stable and consistent API that allows developers the ability to programmatically manage different storage arrays and leverage the hardware accelerated features provided.

This library is used as a building block for other higher level management tools and applications. End system administrators can also use it as a tool to manually manage storage and automate storage management tasks with the use of scripts.

The **`libStorageMgmt`** package allows operations such as:

- List storage pools, volumes, access groups, or file systems.
- Create and delete volumes, access groups, file systems, or NFS exports.
- Grant and remove access to volumes, access groups, or initiators.
- Replicate volumes with snapshots, clones, and copies.
- Create and delete access groups and edit members of a group.

Server resources such as CPU and interconnect bandwidth are not utilized because the operations are all done on the array.

The package provides:

- A stable C and Python API for client application and plug-in developers.
- A commandl line interface that utilizes the library (**`lsmcli`**).
- A daemon that executes the plug-in (**`lsmd`**).
- A simulator plug-in that allows the testing of client applications (**`sim`**).
- Plug-in architecture for interfacing with arrays.

Warning

This library and its associated tool have the ability to destroy any and all data located on the arrays it manages. It is highly recommended to develop and test applications and scripts against the storage simulator pulug-in to remove any logic errors before working with production systems. Testing applications and scripts on actual non-production hardware before deploying to production is also strongly encouraged if possible.

The **`libStorageMgmt`** package in Red Hat Enterprise Linux 7 adds a default udev rule to handle the REPORTED LUNS DATA HAS CHANGED unit attention.

When a storage configuration change has taken place, one of several Unit Attention ASC/ASCQ codes reports the change. A uevent is then generated and is rescanned automatically with **`sysfs`**.

The file **/lib/udev/rules.d/90-scsi-ua.rules** contains example rules to enumerate other events that the kernel can generate.

The **libStorageMgmt** library uses a plug-in architecture to accommodate differences in storage arrays. For more information on **libStorageMgmt** plug-ins and how to write them, refer to Red Hat's *Developer Guide*.

27.2. Terminology from libStorageMgmt

Different array vendors and storage standards use different terminology to refer to similar functionality. This library uses the following terminology.

Storage array

Any storage system that provides block access (FC, FCoE, iSCSI) or file access through Network Attached Storage (NAS).

Volume

Storage Area Network (SAN) Storage Arrays can expose a volume to the Host Bus Adapter (HBA) over different transports, such as FC, iSCSI, or FCoE. The host OS treats it as block devices. One volume can be exposed to many disks if **multipath[2]** is enabled).

This is also known as the Logical Unit Number (LUN), StorageVolume with SNIA terminology, or virtual disk.

Pool

A group of storage spaces. File systems or volumes can be created from a pool. Pools can be created from disks, volumes, and other pools. A pool may also hold RAID settings or thin provisioning settings.

This is also known as a StoragePool with SNIA Terminology.

Snapshot

A point in time, read only, space efficent copy of data.

This is also known as a read only snapshot.

Clone

A point in time, read writeable, space efficent copy of data.

This is also known as a read writeable snapshot.

Copy

A full bitwise copy of the data. It occupies the full space.

Mirror

A continuously updated copy (synchronous and asynchronous).

Access group

Collections of iSCSI, FC, and FCoE initiators which are granted access to one or more storage volumes. This ensures that only storage volumes are accessibly by the specified initiators.

This is also known as an initiator group.

Access Grant

Exposing a volume to a specified access group or initiator. The **libStorageMgmt** library currently does not support LUN mapping with the ability to choose a specific logical unit number. The **libStorageMgmt** library allows the storage array to select the next available LUN for assignment. If configuring a boot from SAN or masking more than 256 volumes be sure to read the OS, Storage Array, or HBA documents.

Access grant is also known as LUN Masking.

System

Represents a storage array or a direct attached storage RAID.

File system

A Network Attached Storage (NAS) storage array can expose a file system to host an OS through an IP network, using either NFS or CIFS protocol. The host OS treats it as a mount point or a folder containing files depending on the client operating system.

Disk

The physical disk holding the data. This is normally used when creating a pool with RAID settings.

This is also known as a DiskDrive using SNIA Terminology.

Initiator

In Fibre Channel (FC) or Fibre Channel over Ethernet (FCoE), the intiator is the World Wide Port Name (WWPN) or World Wide Node Name (WWNN). In iSCSI, the initiator is the iSCSI Qualified Name (IQN). In NFS or CIFS, the initiator is the host name or the IP address of the host.

Child dependency

Some arrays have an implicit relationship between the origin (parent volume or file system) and the child (such as a snapshot or a clone). For example, it is impossible to delete the parent if it has one or more depend children. The API provides methods to determine if any such relationship exists and a method to remove the dependency by replicating the required blocks.

27.3. Installation

To install **libStorageMgmt** for use of the command line, required run-time libraries and simulator plug-ins use the following command:

```
$ sudo yum install libstoragemgmt libstoragemgmt-python
```

To develop C applications that utilize the library, install the **libstoragemgmt-devel** and, optionally, the **libstorage-debuginfo** packages with the following command:

```
$ sudo yum install libstoragemgmt-devel libstoragemgmt-debuginfo
```

To install **libStorageMgmt** for use with hardware arrays, select one or more of the appropriate plug-in packages with the following command:

```
$ sudo yum install libstoragemgmt-name-plugin
```

The following plug-ins that are available include:

libstoragemgmt-smis-plugin

Generic SMI-S array support.

libstoragemgmt-netapp-plugin

Specific support for NetApp files.

libstoragemgmt-nstor-plugin

Specific support for NexentaStor.

libstoragemgmt-targetd-plugin

Specific support for targetd.

The daemon is then installed and configured to run at start up but will not do so until the next reboot. To use it immediately without rebooting, start the daemon manually.

To manage an array requires support through a plug-in. The base install package includes open source plug-ins for a number of different vendors. Additional plug-in packages will be available separately as array support improves. Currently supported hardware is constantly changing and improving. The project web page has the latest information about which arrays and which specific features of each array are supported, and can be accessed at http://libstoragemgmt.sourceforge.net/supported_hardware.html.

The libStorageMgmt daemon (**lsmd**) behaves like any standard service for the system.

To check on the status of libStorageMgmt use:

```
$ sudo systemctl status libstoragemgmt
```

To stop the service use:

```
$ sudo systemctl stop libstoragemgmt
```

To start the service use:

```
$ sudo systemctl start libstoragemgmt
```

27.4. Use of the libStorageMgmt

To use **libStorageMgmt** interactively, use the **lsmcli** command.

The **lsmcli** tool requires two things to run:

- A Uniform Resource Identifier (URI) which is used to identify the plug-in to connect to the array and any configurable options the array requires.

- A valid username and password for the array.

URI has the following form:

plugin+*optional-transport*://*username*@*host*:*port*/?*query-string-parameters*

Each plug-in has different requirements for what is needed.

Example 27.1. Examples of different plug-in requirements

Simulator plug-in that requires no user name or password

```
sim://
```

NetApp plug-in over SSL with user name root

```
ontap+ssl://root@filer.company.com/
```

SMI-S plug-in over SSL for EMC array

```
smis+ssl://admin@provider.com:5989/?namespace=root/emc
```

For more examples refer to https://sourceforge.net/p/libstoragemgmt/wiki/URISyntax/.

There are three options to use the URI:

1. Pass the URI as part of the command.

```
$ lsmcli -u sim://...
```

2. Store the URI in an environmental vairable.

```
$ export LSMCLI_URI=sim:// && lsmcli ...
```

3. Place the URI in the file **~/.lsmcli**, which contains name-value pairs separated by "=". The only currently supported configuration is 'uri'.

Determining which URI to use needs to be done in this order. If all three are supplied, only the first one on the command line will be used.

Supply the password by specifying -P on the command line or by placing it in an environmental variable LSMCLI_PASSWORD.

Example 27.2. Examples of `lsmcli`

An example for using the command line to create a new volume and making it visible to an initiator.

List arrays that are serviced by this connection.

```
$ lsmcli list --type SYSTEMS
ID     | Name                           | Status
-------+--------------------------------+--------
sim-01 | LSM simulated storage plug-in | OK
```

List storage pools.

```
$ lsmcli list --type POOLS -H
ID   | Name          | Total space          | Free space           |
System ID
-----+---------------+----------------------+----------------------+--
---------
POO2 | Pool 2        | 18446744073709551616 | 18446744073709551616 |
sim-01
POO3 | Pool 3        | 18446744073709551616 | 18446744073709551616 |
sim-01
POO1 | Pool 1        | 18446744073709551616 | 18446744073709551616 |
sim-01
POO4 | lsm_test_aggr | 18446744073709551616 | 18446744073709551616 |
sim-01
```

Create a volume.

```
$ lsmcli volume-create --name volume_name --size 20G --pool POO1 -H
ID   | Name        | vpd83                            | bs  | #blocks
| status | ...
-----+-------------+----------------------------------+-----+---------
-+--------+----
Vol1 | volume_name | F7DDF7CA945C66238F593BC38137BD2F | 512 | 41943040
| OK     | ...
```

Create an access group with an iSCSI initiator in it.

```
$ lsmcli --create-access-group example_ag --id iqn.1994-
05.com.domain:01.89bd01 --type ISCSI --system sim-01
ID                               | Name       | Initiator ID
|SystemID
---------------------------------+------------+----------------------
-----------+--------
782d00c8ac63819d6cca7069282e03a0 | example_ag | iqn.1994-
05.com.domain:01.89bd01 |sim-01
```

Create an access group with an iSCSI intiator in it:

```
$ lsmcli access-group-create --name example_ag --init iqn.1994-
05.com.domain:01.89bd01 --init-type ISCSI --sys sim-01
ID                               | Name       | Initiator IDs
| System ID
---------------------------------+------------+----------------------
-----------+-----------
782d00c8ac63819d6cca7069282e03a0 | example_ag | iqn.1994-
05.com.domain:01.89bd01 | sim-01
```

Allow the access group visibility to the newly created volume:

```
$ lsmcli access-group-grant --ag 782d00c8ac63819d6cca7069282e03a0 --vol
Vol1 --access RW
```

The design of the library provides for a process separation between the client and the plug-in by means of *inter-process communication* (IPC). This prevents bugs in the plug-in from crashing the client application. It also provides a means for plug-in writers to write plug-ins with a license of their own choosing. When a client opens the library passing a URI, the client library looks at the URI to determine which plug-in should be used.

The plug-ins are technically stand alone applications but they are designed to have a file descriptor passed to them on the command line. The client library then opens the appropriate Unix domain socket which causes the daemon to fork and execute the plug-in. This gives the client library a point to point communcation channel with the plug-in. The daemon can be restarted without affecting existing clients. While the client has the library open for that plug-in, the plug-in process is running. After one or more commands are sent and the plug-in is closed, the plug-in process cleans up and then exits.

For a sequence diagram on this process see https://sourceforge.net/p/libstoragemgmt/wiki/Architecture/.

The default behavior of lsmcli is to wait until the operation is completee. Depending on the requested operations, this could potentially could take many hours. To allow a return to normal usage, it is possible to use the **-b** option on the command line. If the exit code is 0 the command is completed. If the exit code is 7 the command is in progress and a job identifier is written to standard output. The user or script can then take the job ID and query the status of the command as needed by using **lsmcli --jobstatus *JobID***. If the job is now completed, the exit value will be 0 and the results printed to standard output. If the command is still in progress, the return value will be 7 and the percentage complete will be printed to the standard output.

Example 27.3. An asynchronous example

Create a volume passing the **-b** option so that the command returns immediately.

```
$ lsmcli volume-create --name async_created --size 20G --pool POO1 -b
JOB_3
```

Check to see what the exit value was, remembering that 7 indicates the job is still in progress.

```
$ echo $?
7
```

Check to see if the job is completed.

```
$ lsmcli job-status --job JOB_3
33
```

Check to see what the exit value was, remembering that 7 indicates the job is still in progress so the standard output is the percentage done or 33% based on the above screen.

```
$ echo $?
7
```

Wait some more and check it again, remembering that exit 0 means success and standard out displays the new volume.

```
$ lsmcli job-status --job JOB_3
ID   | Name          | vpd83                                | Block Size
```

```
| ...
-----+--------------+----------------------------------+-------------
+-----
Vol2 | async_created | 855C9BA51991B0CC122A3791996F6B15 | 512         |
...
```

For scripting, pass the **-t *SeparatorCharacters*** option. This will make it easier to parse the output.

Example 27.4. Scripting examples

```
$ lsmcli list --type volumes -t#
Vol1#volume_name#049167B5D09EC0A173E92A63F6C3EA2A#512#41943040#21474836
480#OK#sim-01#POO1
Vol2#async_created#3E771A2E807F68A32FA5E15C235B60CC#512#41943040#214748
36480#OK#sim-01#POO1
```

```
$ lsmcli list --type volumes -t " | "
Vol1 | volume_name | 049167B5D09EC0A173E92A63F6C3EA2A | 512 | 41943040
| 21474836480 | OK | 21474836480 | sim-01 | POO1
Vol2 | async_created | 3E771A2E807F68A32FA5E15C235B60CC | 512 |
41943040 | 21474836480 | OK | sim-01 | POO1
```

```
$ lsmcli list --type volumes -s
----------------------------------------------
ID          | Vol1
Name        | volume_name
VPD83       | 049167B5D09EC0A173E92A63F6C3EA2A
Block Size  | 512
#blocks     | 41943040
Size        | 21474836480
Status      | OK
System ID   | sim-01
Pool ID     | POO1
----------------------------------------------
ID          | Vol2
Name        | async_created
VPD83       | 3E771A2E807F68A32FA5E15C235B60CC
Block Size  | 512
#blocks     | 41943040
Size        | 21474836480
Status      | OK
System ID   | sim-01
Pool ID     | POO1
----------------------------------------------
```

It is recommended to use the Python library for non-trivial scripting.

For more information on **lsmcli**, refer to the man pages or the command **lsmcli --help**.

27.5. libStorageMgmt Documentation

For more information, refer to the following websites:

- Official website: https://sourceforge.net/projects/libstoragemgmt/.
- Project wiki: https://sourceforge.net/p/libstoragemgmt/wiki/Home/.

Appendix A. Revision History

Revision 3-68	**Thu Aug 18 2016**	**Milan Navratil**
Preparing document for 7.3 Beta publication.		
Revision 3-67	**Fri Jun 17 2016**	**Milan Navratil**
An asynchronous update.		
Revision 3-64	**Wed Nov 11 2015**	**Jana Heves**
Version for 7.2 GA release.		
Revision 3-33	**Wed Feb 18 2015**	**Jacquelynn East**
Version for 7.1 GA		
Revision 3-26	**Wed Jan 21 2015**	**Jacquelynn East**
Added overview of Ceph		
Revision 3-22	**Thu Dec 4 2014**	**Jacquelynn East**
7.1 Beta		
Revision 3-4	**Thu Jul 17 2014**	**Jacquelynn East**
Added new chapter on targetcli		
Revision 3-1	**Tue Jun 3 2014**	**Jacquelynn East**
Version for 7.0 GA release		

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- XFS, Repairing an XFS File System