Red Hat Enterprise Linux 9.0

Managing file systems

Creating, modifying, and administering file systems in Red Hat Enterprise Linux 9

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Abstract

Red Hat Enterprise Linux supports a variety of file systems. Each type of file system solves different problems and their usage is application specific. Use the information about the key differences and considerations to select and deploy the appropriate file system based on your specific application requirements. The supported file systems include local on-disk file systems XFS and ext4, network and client-and-server file systems NFS and SMB, as well as a combined local storage and file system management solution, Stratis. You can perform several operations with a file system such as creating, mounting, backing up, restoring, checking and repairing, as well as limiting the storage space by using quotas.

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CHAPTER 1. OVERVIEW OF AVAILABLE FILE SYSTEMS

Choosing the file system that is appropriate for your application is an important decision due to the large number of options available and the trade-offs involved.

The following sections describe the file systems that Red Hat Enterprise Linux 9 includes by default, and recommendations on the most suitable file system for your application.

1.1. TYPES OF FILE SYSTEMS

Red Hat Enterprise Linux 9 supports a variety of file systems (FS). Different types of file systems solve different kinds of problems, and their usage is application specific. At the most general level, available file systems can be grouped into the following major types:

Table 1.1. Types of file systems and their use cases

Type	File system	Attributes and use cases
Disk or local FS	XFS	XFS is the default file system in RHEL. Red Hat recommends deploying XFS as your local file system unless there are specific reasons to do otherwise: for example, compatibility or corner cases around performance.
	ext4	ext4 has the benefit of familiarity in Linux, having evolved from the older ext2 and ext3 file systems. In many cases, it rivals XFS on performance. Support limits for ext4 filesystem and file sizes are lower than those on XFS.
Network or client-and-server FS	NFS	Use NFS to share files between multiple systems on the same network.
	SMB	Use SMB for file sharing with Microsoft Windows systems.
Shared storage or shared disk FS	GFS2	GFS2 provides shared write access to members of a compute cluster. The emphasis is on stability and reliability, with the functional experience of a local file system as possible. SAS Grid, Tibco MQ, IBM Websphere MQ, and Red Hat Active MQ have been deployed successfully on GFS2.
Volume-managing FS	Stratis	Stratis is a volume manager built on a combination of XFS and LVM. The purpose of Stratis is to emulate capabilities offered by volume-managing file systems like Btrfs and ZFS. It is possible to build this stack manually, but Stratis reduces configuration complexity, implements best practices, and consolidates error information.

1.2. LOCAL FILE SYSTEMS

Local file systems are file systems that run on a single, local server and are directly attached to storage.

For example, a local file system is the only choice for internal SATA or SAS disks, and is used when your server has internal hardware RAID controllers with local drives. Local file systems are also the most common file systems used on SAN attached storage when the device exported on the SAN is not shared.

All local file systems are POSIX-compliant and are fully compatible with all supported Red Hat Enterprise Linux releases. POSIX-compliant file systems provide support for a well-defined set of system calls, such as **read()**, **write()**, and **seek()**.

When considering a file system choice, choose a file system based on how large the file system needs to be, what unique features it must have, and how it performs under your workload.

Available local file systems

- XFS
- ext4

1.3. THE XFS FILE SYSTEM

XFS is a highly scalable, high-performance, robust, and mature 64-bit journaling file system that supports very large files and file systems on a single host. It is the default file system in Red Hat Enterprise Linux 9. XFS was originally developed in the early 1990s by SGI and has a long history of running on extremely large servers and storage arrays.

The features of XFS include:

Reliability

- Metadata journaling, which ensures file system integrity after a system crash by keeping a record of file system operations that can be replayed when the system is restarted and the file system remounted
- Extensive run-time metadata consistency checking
- Scalable and fast repair utilities
- Quota journaling. This avoids the need for lengthy quota consistency checks after a crash.

Scalability and performance

- Supported file system size up to 1024 TiB
- Ability to support a large number of concurrent operations
- B-tree indexing for scalability of free space management
- Sophisticated metadata read-ahead algorithms
- Optimizations for streaming video workloads

Allocation schemes

- Extent-based allocation
- Stripe-aware allocation policies
- Delayed allocation
- Space pre-allocation
- Dynamically allocated inodes

Other features

- Reflink-based file copies
- Tightly integrated backup and restore utilities
- Online defragmentation
- Online file system growing
- Comprehensive diagnostics capabilities
- Extended attributes (**xattr**). This allows the system to associate several additional name/value pairs per file.
- Project or directory quotas. This allows quota restrictions over a directory tree.
- Subsecond timestamps

Performance characteristics

XFS has a high performance on large systems with enterprise workloads. A large system is one with a relatively high number of CPUs, multiple HBAs, and connections to external disk arrays. XFS also performs well on smaller systems that have a multi-threaded, parallel I/O workload.

XFS has a relatively low performance for single threaded, metadata-intensive workloads: for example, a workload that creates or deletes large numbers of small files in a single thread.

1.4. THE EXT4 FILE SYSTEM

The ext4 file system is the fourth generation of the ext file system family. It was the default file system in Red Hat Enterprise Linux 6.

The ext4 driver can read and write to ext2 and ext3 file systems, but the ext4 file system format is not compatible with ext2 and ext3 drivers.

ext4 adds several new and improved features, such as:

- Supported file system size up to 50 TiB
- Extent-based metadata
- Delayed allocation

- Journal checksumming
- Large storage support

The extent-based metadata and the delayed allocation features provide a more compact and efficient way to track utilized space in a file system. These features improve file system performance and reduce the space consumed by metadata. Delayed allocation allows the file system to postpone selection of the permanent location for newly written user data until the data is flushed to disk. This enables higher performance since it can allow for larger, more contiguous allocations, allowing the file system to make decisions with much better information.

File system repair time using the **fsck** utility in ext4 is much faster than in ext2 and ext3. Some file system repairs have demonstrated up to a six-fold increase in performance.

1.5. COMPARISON OF XFS AND EXT4

XFS is the default file system in RHEL. This section compares the usage and features of XFS and ext4.

Metadata error behavior

In ext4, you can configure the behavior when the file system encounters metadata errors. The default behavior is to simply continue the operation. When XFS encounters an unrecoverable metadata error, it shuts down the file system and returns the **EFSCORRUPTED** error.

Quotas

In ext4, you can enable quotas when creating the file system or later on an existing file system. You can then configure the quota enforcement using a mount option.
XFS quotas are not a remountable option. You must activate quotas on the initial mount.

Running the **quotacheck** command on an XFS file system has no effect. The first time you turn on quota accounting, XFS checks quotas automatically.

File system resize

XFS has no utility to reduce the size of a file system. You can only increase the size of an XFS file system. In comparison, ext4 supports both extending and reducing the size of a file system.

Inode numbers

The ext4 file system does not support more than 2^{32} inodes.
XFS supports dynamic inode allocation. The amount of space inodes can consume on an XFS filesystem is calculated as a percentage of the total filesystem space. To prevent the system from running out of inodes, an administrator can tune this percentage after the filesystem has been created, given there is free space left on the file system.

Certain applications cannot properly handle inode numbers larger than 2^{32} on an XFS file system. These applications might cause the failure of 32-bit stat calls with the **EOVERFLOW** return value. Inode number exceed 2^{32} under the following conditions:

- The file system is larger than 1 TiB with 256-byte inodes.
- The file system is larger than 2 TiB with 512-byte inodes.

If your application fails with large inode numbers, mount the XFS file system with the **-o inode32** option to enforce inode numbers below 2^{32}. Note that using **inode32** does not affect inodes that are already allocated with 64-bit numbers.

IMPORTANT

Do *not* use the **inode32** option unless a specific environment requires it. The **inode32** option changes allocation behavior. As a consequence, the **ENOSPC** error might occur if no space is available to allocate inodes in the lower disk blocks.

1.6. CHOOSING A LOCAL FILE SYSTEM

To choose a file system that meets your application requirements, you must understand the target system on which you will deploy the file system. In general, use XFS unless you have a specific use case for ext4.

XFS

For large-scale deployments, use XFS, particularly when handling large files (hundreds of megabytes) and high I/O concurrency. XFS performs optimally in environments with high bandwidth (greater than 200MB/s) and more than 1000 IOPS. However, it consumes more CPU resources for metadata operations compared to ext4 and does not support file system shrinking.

ext4

For smaller systems or environments with limited I/O bandwidth, ext4 might be a better fit. It performs better in single-threaded, lower I/O workloads and environments with lower throughput requirements. ext4 also supports offline shrinking, which can be beneficial if resizing the file system is a requirement.

Benchmark your application’s performance on your target server and storage system to ensure the selected file system meets your performance and scalability requirements.

Table 1.2. Summary of local file system recommendations

Scenario	Recommended file system
No special use case	XFS
Large server	XFS
Large storage devices	XFS
Large files	XFS
Multi-threaded I/O	XFS
Single-threaded I/O	ext4
Limited I/O capability (under 1000 IOPS)	ext4
Limited bandwidth (under 200MB/s)	ext4
CPU-bound workload	ext4
Support for offline shrinking	ext4

1.7. NETWORK FILE SYSTEMS

Network file systems, also referred to as client/server file systems, enable client systems to access files that are stored on a shared server. This makes it possible for multiple users on multiple systems to share files and storage resources.

Such file systems are built from one or more servers that export a set of file systems to one or more clients. The client nodes do not have access to the underlying block storage, but rather interact with the storage using a protocol that allows for better access control.

Available network file systems

- The most common client/server file system for RHEL customers is the NFS file system. RHEL provides both an NFS server component to export a local file system over the network and an NFS client to import these file systems.
- RHEL also includes a CIFS client that supports the popular Microsoft SMB file servers for Windows interoperability. The userspace Samba server provides Windows clients with a Microsoft SMB service from a RHEL server.

1.8. SHARED STORAGE FILE SYSTEMS

Shared storage file systems, sometimes referred to as cluster file systems, give each server in the cluster direct access to a shared block device over a local storage area network (SAN).

Comparison with network file systems

Like client/server file systems, shared storage file systems work on a set of servers that are all members of a cluster. Unlike NFS, however, no single server provides access to data or metadata to other members: each member of the cluster has direct access to the same storage device (the *shared storage*), and all cluster member nodes access the same set of files.

Concurrency

Cache coherency is key in a clustered file system to ensure data consistency and integrity. There must be a single version of all files in a cluster visible to all nodes within a cluster. The file system must prevent members of the cluster from updating the same storage block at the same time and causing data corruption. In order to do that, shared storage file systems use a cluster wide-locking mechanism to arbitrate access to the storage as a concurrency control mechanism. For example, before creating a new file or writing to a file that is opened on multiple servers, the file system component on the server must obtain the correct lock.

The requirement of cluster file systems is to provide a highly available service like an Apache web server. Any member of the cluster will see a fully coherent view of the data stored in their shared disk file system, and all updates will be arbitrated correctly by the locking mechanisms.

Performance characteristics

Shared disk file systems do not always perform as well as local file systems running on the same system due to the computational cost of the locking overhead. Shared disk file systems perform well with workloads where each node writes almost exclusively to a particular set of files that are not shared with other nodes or where a set of files is shared in an almost exclusively read-only manner across a set of nodes. This results in a minimum of cross-node cache invalidation and can maximize performance.

Setting up a shared disk file system is complex, and tuning an application to perform well on a shared disk file system can be challenging.

Available shared storage file systems

- Red Hat Enterprise Linux provides the GFS2 file system. GFS2 comes tightly integrated with the Red Hat Enterprise Linux High Availability Add-On and the Resilient Storage Add-On.

Red Hat Enterprise Linux supports GFS2 on clusters that range in size from 2 to 16 nodes.

1.9. CHOOSING BETWEEN NETWORK AND SHARED STORAGE FILE SYSTEMS

When choosing between network and shared storage file systems, consider the following points:

- NFS-based network file systems are an extremely common and popular choice for environments that provide NFS servers.
- Network file systems can be deployed using very high-performance networking technologies like Infiniband or 10 Gigabit Ethernet. This means that you should not turn to shared storage file systems just to get raw bandwidth to your storage. If the speed of access is of prime importance, then use NFS to export a local file system like XFS.
- Shared storage file systems are not easy to set up or to maintain, so you should deploy them only when you cannot provide your required availability with either local or network file systems.
- A shared storage file system in a clustered environment helps reduce downtime by eliminating the steps needed for unmounting and mounting that need to be done during a typical fail-over scenario involving the relocation of a high-availability service.

Red Hat recommends that you use network file systems unless you have a specific use case for shared storage file systems. Use shared storage file systems primarily for deployments that need to provide high-availability services with minimum downtime and have stringent service-level requirements.

1.10. VOLUME-MANAGING FILE SYSTEMS

Volume-managing file systems integrate the entire storage stack for the purposes of simplicity and in-stack optimization.

Available volume-managing file systems

- Red Hat Enterprise Linux 9 provides the Stratis volume manager. Stratis uses XFS for the file system layer and integrates it with LVM, Device Mapper, and other components.

Stratis was first released in Red Hat Enterprise Linux 8.0. It is conceived to fill the gap created when Red Hat deprecated Btrfs. Stratis 1.0 is an intuitive, command line-based volume manager that can perform significant storage management operations while hiding the complexity from the user:

- Volume management
- Pool creation
- Thin storage pools
- Snapshots
- Automated read cache

Stratis offers powerful features, but currently lacks certain capabilities of other offerings that it might be compared to, such as Btrfs or ZFS. Most notably, it does not support CRCs with self healing.

CHAPTER 2. MANAGING LOCAL STORAGE BY USING RHEL SYSTEM ROLES

To manage LVM and local file systems (FS) by using Ansible, you can use the **storage** role. Using the **storage** role enables you to automate administration of file systems on disks and logical volumes on multiple machines.

For more information about RHEL system roles and how to apply them, see Introduction to RHEL system roles.

2.1. CREATING AN XFS FILE SYSTEM ON A BLOCK DEVICE BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to automate the creation of an XFS file system on block devices.

NOTE

The **storage** role can create a file system only on an unpartitioned, whole disk or a logical volume (LV). It cannot create the file system on a partition.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Create an XFS file system on a block device
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_volumes:
          - name: barefs
            type: disk
            disks:
              - sdb
            fs_type: xfs
```

The settings specified in the example playbook include the following:

name: barefs

The volume name (***barefs*** in the example) is currently arbitrary. The **storage** role identifies the volume by the disk device listed under the **disks** attribute.

fs_type: *<file_system>*

You can omit the **fs_type** parameter if you want to use the default file system XFS.

disks: *<list_of_disks_and_volumes>*

A YAML list of disk and LV names. To create the file system on an LV, provide the LVM setup under the **disks** attribute, including the enclosing volume group. For details, see Creating or resizing a logical volume by using the storage RHEL system role .
Do not provide the path to the LV device.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

2.2. PERSISTENTLY MOUNTING A FILE SYSTEM BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to persistently mount file systems to ensure they remain available across system reboots and are automatically mounted on startup. If the file system on the device you specified in the playbook does not exist, the role creates it.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Persistently mount a file system
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_volumes:
          - name: barefs
            type: disk
            disks:
              - sdb
            fs_type: xfs
```

```
        mount_point: /mnt/data
        mount_user: somebody
        mount_group: somegroup
        mount_mode: 0755
```

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

2.3. CREATING OR RESIZING A LOGICAL VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to create and resize LVM logical volumes. The role automatically creates volume groups if they do not exist.

Use the **storage** role to perform the following tasks:

- To create an LVM logical volume in a volume group consisting of many disks
- To resize an existing file system on LVM
- To express an LVM volume size in percentage of the pool's total size

If the volume group does not exist, the role creates it. If a logical volume exists in the volume group, it is resized if the size does not match what is specified in the playbook.

If you are reducing a logical volume, to prevent data loss you must ensure that the file system on that logical volume is not using the space in the logical volume that is being reduced.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Create logical volume
```

```
ansible.builtin.include_role:
  name: redhat.rhel_system_roles.storage
vars:
  storage_pools:
    - name: myvg
      disks:
        - sda
        - sdb
        - sdc
      volumes:
        - name: mylv
          size: 2G
          fs_type: ext4
          mount_point: /mnt/data
```

The settings specified in the example playbook include the following:

size: *<size>*

You must specify the size by using units (for example, GiB) or percentage (for example, 60%).

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Verify that specified volume has been created or resized to the requested size:

```
# ansible managed-node-01.example.com -m command -a 'lvs myvg'
```

2.4. ENABLING ONLINE BLOCK DISCARD BY USING THE STORAGE RHEL SYSTEM ROLE

You can mount an XFS file system with the online block discard option to automatically discard unused blocks.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Enable online block discard
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_volumes:
          - name: barefs
            type: disk
            disks:
              - sdb
            fs_type: xfs
            mount_point: /mnt/data
            mount_options: discard
```

   For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

   Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Verify that online block discard option is enabled:

```
# ansible managed-node-01.example.com -m command -a 'findmnt /mnt/data'
```

2.5. CREATING AND MOUNTING A FILE SYSTEM BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to create and mount file systems that persist across reboots. The role automatically adds entries to **/etc/fstab** to ensure persistent mounting.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    -name: Create and mount a file system
    ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
    vars:
      storage_volumes:
        - name: barefs
          type: disk
          disks:
            - sdb
          fs_type: ext4
          fs_label: label-name
          mount_point: /mnt/data
```

The settings specified in the example playbook include the following:

disks: *<list_of_devices>*
: A YAML list of device names that the role uses when it creates the volume.

fs_type: *<file_system>*
: Specifies the file system the role should set on the volume. You can select **xfs**, **ext3**, **ext4**, **swap**, or **unformatted**.

label-name: *<file_system_label>*
: Optional: sets the label of the file system.

mount_point: *<directory>*
: Optional: if the volume should be automatically mounted, set the **mount_point** variable to the directory to which the volume should be mounted.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

2.6. CONFIGURING A RAID VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE

With the **storage** system role, you can configure a RAID volume on RHEL by using Red Hat Ansible Automation Platform and Ansible-Core. Create an Ansible playbook with the parameters to configure a RAID volume to suit your requirements.

> **WARNING**
>
> Device names might change in certain circumstances, for example, when you add a new disk to a system. Therefore, to prevent data loss, use persistent naming attributes in the playbook. For more information about persistent naming attributes, see Persistent naming attributes.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Create a RAID on sdd, sde, sdf, and sdg
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_safe_mode: false
        storage_volumes:
          - name: data
            type: raid
            disks: [sdd, sde, sdf, sdg]
            raid_level: raid0
            raid_chunk_size: 32 KiB
            mount_point: /mnt/data
            state: present
```

   For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

   Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Verify that the array was correctly created:

```
# ansible managed-node-01.example.com -m command -a 'mdadm --detail
/dev/md/data'
```

2.7. CONFIGURING AN LVM POOL WITH RAID BY USING THE STORAGE RHEL SYSTEM ROLE

Additional resources

With the **storage** system role, you can configure an LVM pool with RAID on RHEL by using Red Hat Ansible Automation Platform. You can set up an Ansible playbook with the available parameters to configure an LVM pool with RAID.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure LVM pool with RAID
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_safe_mode: false
        storage_pools:
          - name: my_pool
            type: lvm
            disks: [sdh, sdi]
            raid_level: raid1
            volumes:
              - name: my_volume
                size: "1 GiB"
                mount_point: "/mnt/app/shared"
                fs_type: xfs
                state: present
```

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Verify that your pool is on RAID:

```
# ansible managed-node-01.example.com -m command -a 'lsblk'
```

Additional resources

- Managing RAID

2.8. CONFIGURING A STRIPE SIZE FOR RAID LVM VOLUMES BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to configure stripe sizes for RAID LVM volumes.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Configure stripe size for RAID LVM volumes
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_safe_mode: false
        storage_pools:
          - name: my_pool
            type: lvm
            disks: [sdh, sdi]
            volumes:
              - name: my_volume
                size: "1 GiB"
                mount_point: "/mnt/app/shared"
```

```
        fs_type: xfs
        raid_level: raid0
        raid_stripe_size: "256 KiB"
        state: present
```

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Verify that stripe size is set to the required size:

```
# ansible managed-node-01.example.com -m command -a 'lvs -o+stripesize /dev/my_pool/my_volume'
```

Additional resources

- Managing RAID

2.9. CONFIGURING AN LVM-VDO VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to create a VDO volume on LVM (LVM-VDO) with enabled compression and deduplication.

> **NOTE**
>
> Because of the **storage** system role use of LVM-VDO, only one volume can be created per pool.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
```

```
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Create LVM-VDO volume under volume group 'myvg'
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_pools:
          - name: myvg
            disks:
              - /dev/sdb
            volumes:
              - name: mylv1
                compression: true
                deduplication: true
                vdo_pool_size: 10 GiB
                size: 30 GiB
                mount_point: /mnt/app/shared
```

The settings specified in the example playbook include the following:

vdo_pool_size: *<size>*

The actual size that the volume takes on the device. You can specify the size in human-readable format, such as 10 GiB. If you do not specify a unit, it defaults to bytes.

size: *<size>*

The virtual size of VDO volume.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- View the current status of compression and deduplication:

```
$ ansible managed-node-01.example.com -m command -a 'lvs -o+vdo_compression,vdo_compression_state,vdo_deduplication,vdo_index_state'
  LV       VG       Attr       LSize   Pool   Origin Data%  Meta%  Move Log Cpy%Sync Convert VDOCompression VDOCompressionState VDODeduplication VDOIndexState
  mylv1   myvg   vwi-a-v---   3.00t vpool0                                                         enabled              online          enabled        online
```

2.10. CREATING A LUKS2 ENCRYPTED VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** role to create and configure a volume encrypted with LUKS by running an Ansible playbook.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Store your sensitive variables in an encrypted file:
    a. Create the vault:

    ```
    $ ansible-vault create ~/vault.yml
    New Vault password: <vault_password>
    Confirm New Vault password: <vault_password>
    ```

    b. After the **ansible-vault create** command opens an editor, enter the sensitive data in the ***<key>*: *<value>*** format:

    ```
    luks_password: <password>
    ```

    c. Save the changes, and close the editor. Ansible encrypts the data in the vault.

2. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  vars_files:
    - ~/vault.yml
  tasks:
    - name: Create and configure a volume encrypted with LUKS
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_volumes:
          - name: barefs
            type: disk
            disks:
              - sdb
            fs_type: xfs
            fs_label: <label>
            mount_point: /mnt/data
            encryption: true
            encryption_password: "{{ luks_password }}"
```

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

3. Validate the playbook syntax:

```
$ ansible-playbook --ask-vault-pass --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

4. Run the playbook:

```
$ ansible-playbook --ask-vault-pass ~/playbook.yml
```

Verification

1. Find the **luksUUID** value of the LUKS encrypted volume:

```
# ansible managed-node-01.example.com -m command -a 'cryptsetup luksUUID
/dev/sdb'

4e4e7970-1822-470e-b55a-e91efe5d0f5c
```

2. View the encryption status of the volume:

```
# ansible managed-node-01.example.com -m command -a 'cryptsetup status luks-
4e4e7970-1822-470e-b55a-e91efe5d0f5c'

/dev/mapper/luks-4e4e7970-1822-470e-b55a-e91efe5d0f5c is active and is in use.
  type:    LUKS2
  cipher:  aes-xts-plain64
  keysize: 512 bits
  key location: keyring
  device:  /dev/sdb
...
```

3. Verify the created LUKS encrypted volume:

```
# ansible managed-node-01.example.com -m command -a 'cryptsetup luksDump
/dev/sdb'

LUKS header information
Version:        2
Epoch:          3
Metadata area:  16384 [bytes]
Keyslots area:  16744448 [bytes]
UUID:           4e4e7970-1822-470e-b55a-e91efe5d0f5c
Label:          (no label)
Subsystem:      (no subsystem)
Flags:          (no flags)

Data segments:
  0: crypt
        offset: 16777216 [bytes]
        length: (whole device)
```

```
      cipher: aes-xts-plain64
      sector: 512 [bytes]
...
```

Additional resources

- Encrypting block devices by using LUKS
- Ansible vault

2.11. CREATING SHARED LVM DEVICES USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to create shared LVM devices if you want your multiple systems to access the same storage at the same time.

This can bring the following notable benefits:

- Resource sharing
- Flexibility in managing storage resources
- Simplification of storage management tasks

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.
- **lvmlockd** is configured on the managed node. For more information, see Configuring LVM to share SAN disks among multiple machines.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  become: true
  tasks:
    - name: Create shared LVM device
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_pools:
          - name: vg1
            disks: /dev/vdb
            type: lvm
            shared: true
            state: present
            volumes:
              - name: lv1
```

```
          size: 4g
          mount_point: /opt/test1
      storage_safe_mode: false
      storage_use_partitions: true
```

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

2.12. RESIZING PHYSICAL VOLUMES BY USING THE STORAGE RHEL SYSTEM ROLE

With the **storage** system role, you can resize LVM physical volumes after resizing the underlying storage or disks from outside of the host. For example, you increased the size of a virtual disk and want to use the extra space in an existing LVM.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.
- The size of the underlying block storage has been changed.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Resize LVM PV size
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_pools:
          - name: myvg
            disks: ["sdf"]
            type: lvm
            grow_to_fill: true
```

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Display the new physical volume size:

```
$ ansible managed-node-01.example.com -m command -a 'pvs'
PV         VG   Fmt Attr PSize PFree
/dev/sdf1  myvg lvm2 a-- 1,99g 1,99g
```

2.13. CREATING AN ENCRYPTED STRATIS POOL BY USING THE STORAGE RHEL SYSTEM ROLE

To secure your data, you can create an encrypted Stratis pool with the **storage** RHEL system role. In addition to a passphrase, you can use Clevis and Tang or TPM protection as an encryption method.

IMPORTANT

You can configure Stratis encryption only on the entire pool.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.
- You can connect to the Tang server. For more information, see Deploying a Tang server with SELinux in enforcing mode.

Procedure

1. Store your sensitive variables in an encrypted file:

   a. Create the vault:

   ```
   $ ansible-vault create ~/vault.yml
   New Vault password: <vault_password>
   Confirm New Vault password: <vault_password>
   ```

   b. After the **ansible-vault create** command opens an editor, enter the sensitive data in the ***<key>*: *<value>*** format:

```
luks_password: <password>
```

c. Save the changes, and close the editor. Ansible encrypts the data in the vault.

2. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  vars_files:
    - ~/vault.yml
  tasks:
    - name: Create a new encrypted Stratis pool with Clevis and Tang
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_pools:
           - name: mypool
             disks:
               - sdd
               - sde
             type: stratis
             encryption: true
             encryption_password: "{{ luks_password }}"
             encryption_clevis_pin: tang
             encryption_tang_url: tang-server.example.com:7500
```

The settings specified in the example playbook include the following:

encryption_password
: Password or passphrase used to unlock the LUKS volumes.

encryption_clevis_pin
: Clevis method that you can use to encrypt the created pool. You can use **tang** and **tpm2**.

encryption_tang_url
: URL of the Tang server.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

3. Validate the playbook syntax:

```
$ ansible-playbook --ask-vault-pass --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

4. Run the playbook:

```
$ ansible-playbook --ask-vault-pass ~/playbook.yml
```

Verification

- Verify that the pool was created with Clevis and Tang configured:

```
$ ansible managed-node-01.example.com -m command -a 'sudo stratis report'
...
                    "clevis_config": {
                        "thp": "j-G4ddvdbVfxpnUbgxlpbe3KutSKmcHttILAtAkMTNA",
                        "url": "tang-server.example.com:7500"
                    },
                    "clevis_pin": "tang",
                    "in_use": true,
                    "key_description": "blivet-mypool",
```

Additional resources

- Ansible vault

CHAPTER 3. MANAGING PARTITIONS USING THE WEB CONSOLE

Learn how to manage file systems on RHEL 9 using the web console.

3.1. DISPLAYING PARTITIONS FORMATTED WITH FILE SYSTEMS IN THE WEB CONSOLE

The **Storage** section in the web console displays all available file systems in the **Filesystems** table. In addition to the list of partitions formatted with file systems, you can also use the page for creating a new storage.

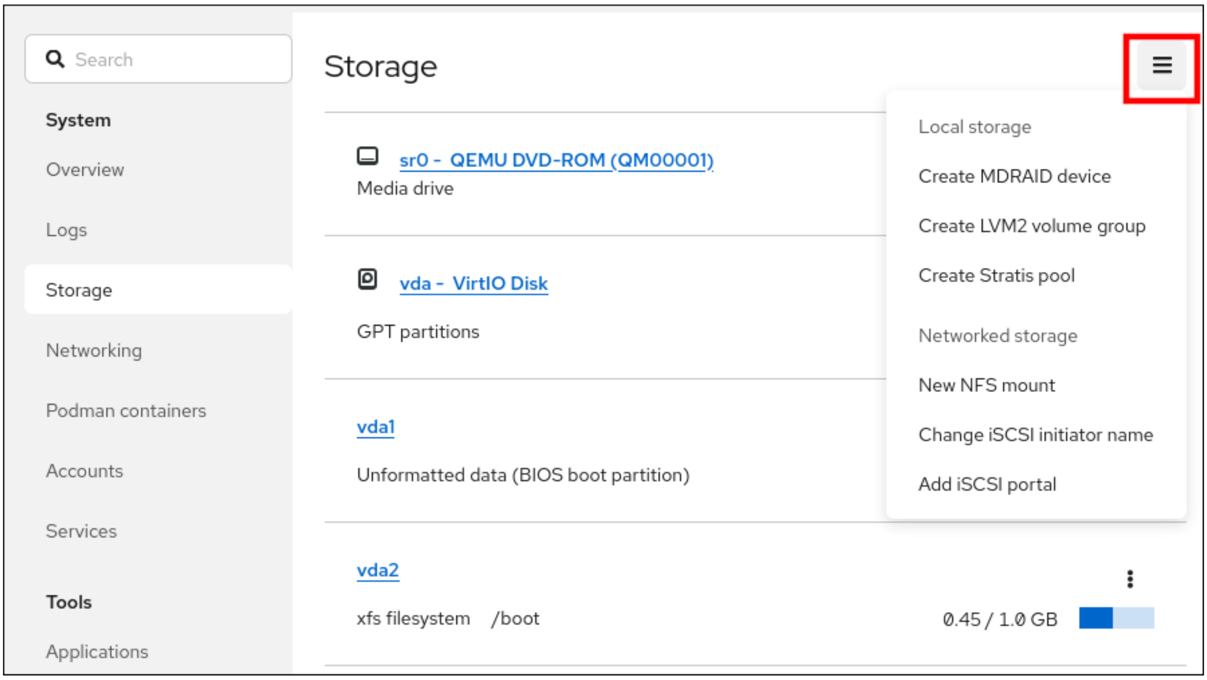
Prerequisites

- The **cockpit-storaged** package is installed on your system.
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click the **Storage** tab.
   In the **Storage** table, you can see all available partitions formatted with file systems, their ID, types, locations, sizes, and how much space is available on each partition.

   You can also use the drop-down menu in the upper-right corner to create new local or networked storage.



3.2. CREATING PARTITIONS IN THE WEB CONSOLE

To create a new partition:

- Use an existing partition table
- Create a partition

Prerequisites

- The **cockpit-storaged** package is installed on your system.
- The web console must be installed and accessible. For details, see Installing the web console.
- An unformatted volume connected to the system is visible in the **Storage** table of the **Storage** tab.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click the **Storage** tab.
3. In the **Storage** table, click the device which you want to partition to open the page and options for that device.
4. On the device page, click the menu button, ⋮ , and select **Create partition table**.
5. In the **Initialize disk** dialog box, select the following:
   a. **Partitioning**:
      - Compatible with all systems and devices (MBR)
      - Compatible with modern system and hard disks > 2TB (GPT)
      - No partitioning
   b. **Overwrite**:
      - Select the **Overwrite existing data with zeros** checkbox if you want the RHEL web console to rewrite the whole disk with zeros. This option is slower because the program has to go through the whole disk, but it is more secure. Use this option if the disk includes any data and you need to overwrite it.
        If you do not select the **Overwrite existing data with zeros** checkbox, the RHEL web console rewrites only the disk header. This increases the speed of formatting.
6. Click **Initialize**.
7. Click the menu button, ⋮ , next to the partition table you created. It is named **Free space** by default.
8. Click **Create partition**.
9. In the **Create partition** dialog box, enter a **Name** for the file system.

10. Add a **Mount point**.
11. In the **Type** drop-down menu, select a file system:
    - **XFS** file system supports large logical volumes, switching physical drives online without outage, and growing an existing file system. Leave this file system selected if you do not have a different strong preference.
    - **ext4** file system supports:
        - Logical volumes
        - Switching physical drives online without outage
        - Growing a file system
        - Shrinking a file system

    Additional option is to enable encryption of partition done by LUKS (Linux Unified Key Setup), which allows you to encrypt the volume with a passphrase.
12. Enter the **Size** of the volume you want to create.
13. Select the **Overwrite existing data with zeros** checkbox if you want the RHEL web console to rewrite the whole disk with zeros. This option is slower because the program has to go through the whole disk, but it is more secure. Use this option if the disk includes any data and you need to overwrite it.
    If you do not select the **Overwrite existing data with zeros** checkbox, the RHEL web console rewrites only the disk header. This increases the speed of formatting.
14. If you want to encrypt the volume, select the type of encryption in the **Encryption** drop-down menu.
    If you do not want to encrypt the volume, select **No encryption**.
15. In the **At boot** drop-down menu, select when you want to mount the volume.
16. In **Mount options** section:
    a. Select the **Mount read only** checkbox if you want the to mount the volume as a read-only logical volume.
    b. Select the **Custom mount options** checkbox and add the mount options if you want to change the default mount option.
17. Create the partition:
    - If you want to create and mount the partition, click the **Create and mount** button.
    - If you want to only create the partition, click the **Create only** button.
      Formatting can take several minutes depending on the volume size and which formatting options are selected.

Verification

- To verify that the partition has been successfully added, switch to the **Storage** tab and check the **Storage** table and verify whether the new partition is listed.

3.3. DELETING PARTITIONS IN THE WEB CONSOLE

You can remove partitions in the web console interface.

Prerequisites

- The **cockpit-storaged** package is installed on your system.
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click the **Storage** tab.
3. Click the device from which you want to delete a partition.
4. On the device page and in the **GPT partitions** section, click the menu button, ⋮ next to the partition you want to delete.
5. From the drop-down menu, select **Delete**.
   The RHEL web console terminates all processes that are currently using the partition and unmount the partition before deleting it.

Verification

- To verify that the partition has been successfully removed, switch to the **Storage** tab and check the **Storage** table.

CHAPTER 4. MOUNTING NFS SHARES

As a system administrator, you can mount remote NFS shares on your system to access shared data.

4.1. SERVICES REQUIRED ON AN NFS CLIENT

Red Hat Enterprise Linux uses a combination of kernel modules and user-space processes to provide access to NFS file shares. The **nfs-utils** package provides the program files for user-space processes. Install the **nfs-utils** package to enable NFS client functionality. Principal services used by the NFS client include the following:

Table 4.1. Services required on an NFS client

Service name	NFS version	Description
nfsidmap	4	A program that services upcalls from the NFSv4 client mapping between NFSv4 names (strings in the form of ***<user@domain>***) and local user and group IDs. It provides similar functionality that **rpc.idmapd** provides on behalf of the NFSv4 server. The difference is that while **rpc.idmapd** is a daemon, **nfsidmap** is invoked on-demand via the kernel request-key mechanism. **nfsidmap** uses two configuration files: **/etc/idmapd.conf** and **/etc/request-key.d/id_resolver.conf**. In most cases the defaults are sufficient and it is unnecessary to modify either of these configuration files.
rpc.statd	3	A daemon that implements the Network Status Monitor protocol. The two main functions of **rpc.statd**: • Listen for requests from the local **lockd** process (the kernel daemon that implements the Network Lock Manager protocol) to monitor network peers (in the case of an NFS client, **rpc.statd** is monitoring the NFS server). • Listen for reboot notifications from remote peers (NFS servers that have rebooted) which it then forwards to **lockd** so it can reclaim any locks it had from those servers. Use the **[statd]** section in the **/etc/nfs.conf** file to configure **rpc.statd**.
rpc-statd.service	3	A **systemd** unit file that starts the **rpc.statd** daemon. Note that it is not necessary to enable or start the service manually, because the **mount.nfs** program will automatically start **rpc-statd.service** (via the **/usr/sbin/start-statd** shell script) the first time it mounts a remote file system using NFSv3. However, if configuring the NFSv3 client to run behind a firewall, it is typically necessary to restart the **rpc-statd.service**.
sm-notify	3	A helper program that sends reboot notifications to remote peers that were monitored by **rpc.statd** whenever the local system reboots. In the case of an NFS client, **sm-notify** is sending reboot notifications to NFS servers so that those servers can drop any locks that were held by the client.

Service name	NFS version	Description
rpc-statd-notify.service	3	A **systemd** unit that triggers **sm-notify**. It runs automatically at system boot, so it is not necessary to manually enable or start the service.
rpc.gssd	3, 4	A daemon that acts on behalf of the kernel to establish a Generic Security Services (GSS) context with a remote peer (typically initiated from the NFS client to the NFS server, but also initiated from the NFS server to the NFS client in the case of NFSv4 callbacks). This process is necessary for securing NFS using Kerberos V5. The **rpc.gssd** program is configured via the **[gssd]** section in the **/etc/nfs.conf** file.
rpc-gssd.service	3, 4	A **systemd** unit file that starts the **rpc.gssd** daemon. It is not necessary to manually enable or start this service, because the service automatically starts on system boot if the **/etc/krb5.keytab** file is present on the system.

Additional resources

- **nfsidmap(8)**, **rpc.statd(8)**, **sm-notify(8)**, **rpc.gssd(8)**, and **nfs.conf(5)** man pages on your system

4.2. PREPARING AN NFSV3 CLIENT TO RUN BEHIND A FIREWALL

An NFS server notifies clients about file locks and the server status. To establish a connection back to the client, you must open the relevant ports in the firewall on the client.

Procedure

1. By default, NFSv3 RPC services use random ports. To enable a firewall configuration, configure fixed port numbers in the **/etc/nfs.conf** file:

   a. In the **[lockd]** section, set a fixed port number for the **nlockmgr** RPC service, for example:

   ```
   port=5555
   ```

   With this setting, the service automatically uses this port number for both the UDP and TCP protocol.

   b. In the **[statd]** section, set a fixed port number for the **rpc.statd** service, for example:

   ```
   port=6666
   ```

   With this setting, the service automatically uses this port number for both the UDP and TCP protocol.

2. Open the relevant ports in **firewalld**:

   ```
   # firewall-cmd --permanent --add-service=rpc-bind
   # firewall-cmd --permanent --add-port={5555/tcp,5555/udp,6666/tcp,6666/udp}
   # firewall-cmd --reload
   ```

3. Restart the **rpc-statd** service:

```
# systemctl restart rpc-statd nfs-server
```

4.3. PREPARING AN NFSV4 CLIENT TO RUN BEHIND A FIREWALL

An NFS server notifies clients about file locks and the server status. To establish a connection back to the client, you must open the relevant ports in the firewall on the client.

> **NOTE**
>
> NFS v4.1 and later uses the pre-existing client port for callbacks, so the callback port cannot be set separately. For more information, see the How do I set the NFS4 client callback port to a specific port? solution.

Prerequisites

- The server uses the NFS 4.0 protocol.

Procedure

- Open the relevant ports in **firewalld**:

```
# firewall-cmd --permanent --add-port=<callback_port>/tcp
# firewall-cmd --reload
```

4.4. MANUALLY MOUNTING AN NFS SHARE

If you do not require that a NFS share is automatically mounted at boot time, you can manually mount it.

> **WARNING**
>
> You can experience conflicts in your NFSv4 **clientid** and their sudden expiration if your NFS clients have the same short hostname. To avoid any possible sudden expiration of your NFSv4 **clientid**, you must use either unique hostnames for NFS clients or configure identifier on each container, depending on what system you are using. For more information, see the Red Hat Knowledgebase solution NFSv4 clientid was expired suddenly due to use same hostname on several NFS clients.

Procedure

- Use the following command to mount an NFS share on a client:

```
# mount <nfs_server_ip_or_hostname>:/<exported_share> <mount point>
```

For example, to mount the **/nfs/projects** share from the **server.example.com** NFS server to **/mnt**, enter:

```
# mount server.example.com:/nfs/projects/ /mnt/
```

Verification

- As a user who has permissions to access the NFS share, display the content of the mounted share:

```
$ ls -l /mnt/
```

4.5. MOUNTING AN NFS SHARE AUTOMATICALLY WHEN THE SYSTEM BOOTS

Automatic mounting of an NFS share during system boot ensures that critical services reliant on centralized data, such as **/home** directories hosted on the NFS server, have seamless and uninterrupted access from the moment the system starts up.

Procedure

1. Edit the **/etc/fstab** file and add a line for the share that you want to mount:

```
<nfs_server_ip_or_hostname>:/<exported_share>     <mount point>    nfs    default   0 0
```

For example, to mount the **/nfs/projects** share from the **server.example.com** NFS server to **/home**, enter:

```
server.example.com:/nfs/projects     /home        nfs  defaults     0 0
```

2. Mount the share:

```
# mount /home
```

Verification

- As a user who has permissions to access the NFS share, display the content of the mounted share:

```
$ ls -l /mnt/
```

Additional resources

- **fstab(5)** man page on your system

4.6. CONNECTING NFS MOUNTS IN THE WEB CONSOLE

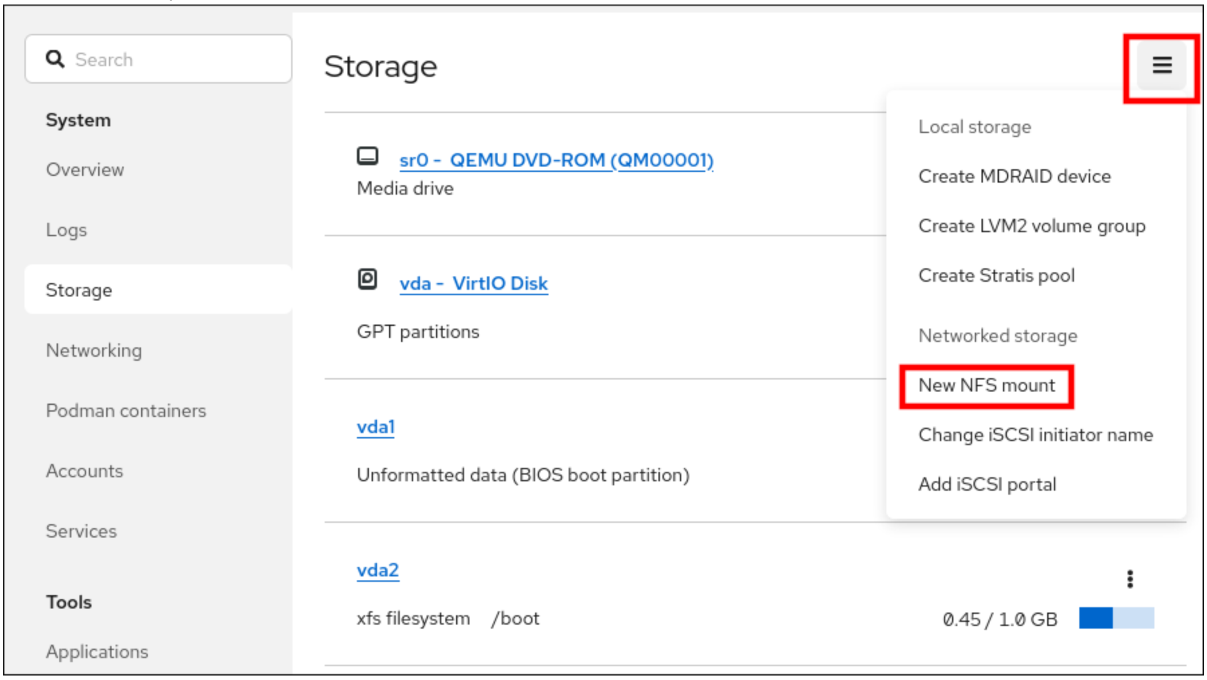
Connect a remote directory to your file system by using NFS.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **cockpit-storaged** package is installed on your system.
- NFS server name or the IP address.
- Path to the directory on the remote server.

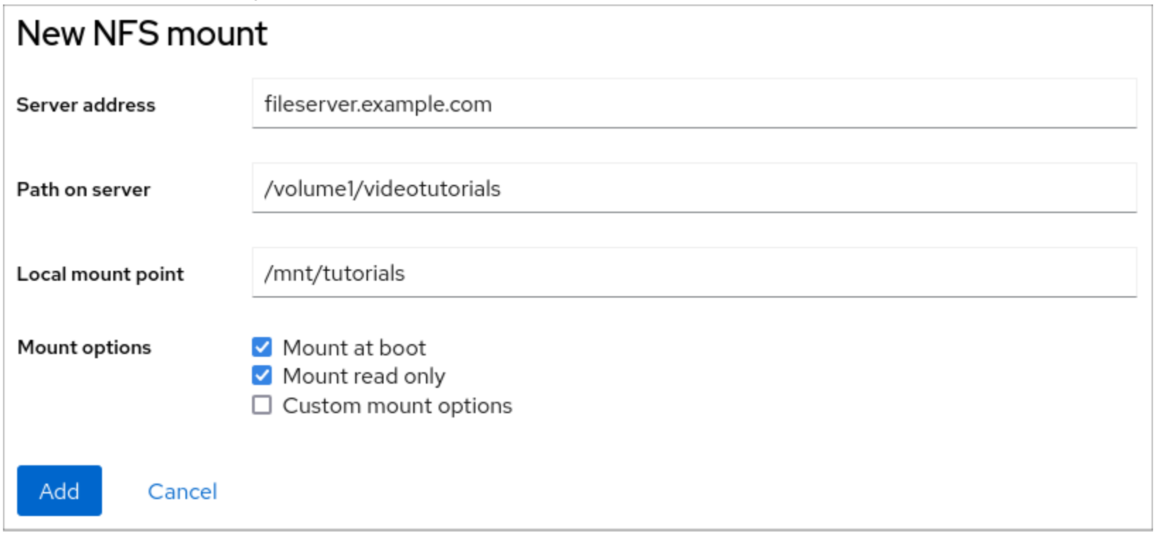
Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the menu button.
4. From the drop-down menu, select **New NFS mount**.



5. In the **New NFS Mount** dialog box, enter the server or IP address of the remote server.
6. In the **Path on Server** field, enter the path to the directory that you want to mount.
7. In the **Local Mount Point** field, enter the path to the directory on your local system where you want to mount the NFS.
8. In the **Mount options** checkbox list, select how you want to mount the NFS. You can select multiple options depending on your requirements.
   - Check the **Mount at boot** box if you want the directory to be reachable even after you restart the local system.
   - Check the **Mount read only** box if you do not want to change the content of the NFS.

- Check the **Custom mount options** box and add the mount options if you want to change the default mount option.



9. Click **Add**.

Verification

- Open the mounted directory and verify that the content is accessible.

4.7. CUSTOMIZING NFS MOUNT OPTIONS IN THE WEB CONSOLE

Edit an existing NFS mount and add custom mount options.

Custom mount options can help you to troubleshoot the connection or change parameters of the NFS mount such as changing timeout limits or configuring authentication.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **cockpit-storaged** package is installed on your system.
- An NFS mount is added to your system.

Procedure

1. Log in to the RHEL 9 web console. For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the NFS mount you want to adjust.
4. If the remote directory is mounted, click **Unmount**.
   You must unmount the directory during the custom mount options configuration. Otherwise, the web console does not save the configuration and this causes an error.

5. Click **Edit**.

6. In the **NFS Mount** dialog box, select **Custom mount option**.

7. Enter mount options separated by a comma. For example:

   - **nfsvers=4**: The NFS protocol version number

   - **soft**: The type of recovery after an NFS request times out

   - **sec=krb5**: The files on the NFS server can be secured by Kerberos authentication. Both the NFS client and server have to support Kerberos authentication.

   For a complete list of the NFS mount options, enter **man nfs** in the command line.

8. Click **Apply**.

9. Click **Mount**.

Verification

- Open the mounted directory and verify that the content is accessible.

4.8. SETTING UP AN NFS CLIENT WITH KERBEROS IN A RED HAT ENTERPRISE LINUX IDENTITY MANAGEMENT DOMAIN

If the NFS server uses Kerberos and is enrolled in an Red Hat Enterprise Linux Identity Management (IdM) domain, your client must also be a member of the domain to be able to mount the shares. This enables you to centrally manage users and groups and to use Kerberos for authentication, integrity protection, and traffic encryption.

Prerequisites

- The NFS client is enrolled in a Red Hat Enterprise Linux Identity Management (IdM) domain.

- The exported NFS share uses Kerberos.

Procedure

1. Obtain a kerberos ticket as an IdM administrator:

```
# kinit admin
```

2. Retrieve the host principal, and store it in the **/etc/krb5.keytab** file:

```
# ipa-getkeytab -s idm_server.idm.example.com -p host/nfs_client.idm.example.com -k
/etc/krb5.keytab
```

   IdM automatically created the **host** principal when you joined the host to the IdM domain.

3. Optional: Display the principals in the **/etc/krb5.keytab** file:

```
# klist -k /etc/krb5.keytab
Keytab name: FILE:/etc/krb5.keytab
```

```
KVNO Principal
---- --------------------------------------------------------------------------
   6 host/nfs_client.idm.example.com@IDM.EXAMPLE.COM
   6 host/nfs_client.idm.example.com@IDM.EXAMPLE.COM
   6 host/nfs_client.idm.example.com@IDM.EXAMPLE.COM
   6 host/nfs_client.idm.example.com@IDM.EXAMPLE.COM
```

4. Use the **ipa-client-automount** utility to configure mapping of IdM IDs:

```
# ipa-client-automount
Searching for IPA server...
IPA server: DNS discovery
Location: default
Continue to configure the system with these values? [no]: yes
Configured /etc/idmapd.conf
Restarting sssd, waiting for it to become available.
Started autofs
```

5. Mount an exported NFS share, for example:

```
# mount -o sec=krb5i server.idm.example.com:/nfs/projects/ /mnt/
```

The **-o sec** option specifies the Kerberos security method.

Verification

1. Log in as an IdM user who has permissions to write on the mounted share.

2. Obtain a Kerberos ticket:

```
$ kinit
```

3. Create a file on the share, for example:

```
$ touch /mnt/test.txt
```

4. List the directory to verify that the file was created:

```
$ ls -l /mnt/test.txt
-rw-r--r--. 1 admin users 0 Feb 15 11:54 /mnt/test.txt
```

Additional resources

- The AUTH_GSS authentication method

4.9. CONFIGURING AN NFS SERVER WITH TLS SUPPORT

Without the **RPCSEC_GSS** protocol, NFS traffic is unencrypted by default. Starting with Red Hat Enterprise Linux 9.6, it is possible to configure NFS with TLS, allowing NFS traffic to be encrypted by default.

Prerequisites

- You have configured an NFSv4 server. For instructions, see Configuring an NFSv4-only server.
- You have a Certificate Authority (CA) certificate.
- You have installed the **ktls-utils** package.

Procedure

1. Create a private key and a certificate signing request (CSR):

```
# openssl req -new -newkey rsa:4096 -noenc \
-keyout /etc/pki/tls/private/server.example.com.key \
-out /etc/pki/tls/private/server.example.com.csr \
-subj "/C=US/ST=State/L=City/O=Organization/CN=server.example.com" \
-addext "subjectAltName=DNS:server.example.com,IP:192.0.2.1"
```

IMPORTANT

Common Name (CN) and DNS must match the hostname. IP must match IP of the host.

2. Send the **/etc/pki/tls/private/server.example.com.csr** file to a CA and request a server certificate. Store the received CA certificate and the server certificate on the host.

3. Import the CA certificate to the systems's truststore:

```
# cp ca.crt /etc/pki/ca-trust/source/anchors
# update-ca-trust
```

4. Move the server certificate to the **/etc/pki/tls/certs/** directory:

```
# mv server.example.com.crt /etc/pki/tls/certs/
```

5. Ensure the SELinux context is correct on the private key and certificates:

```
# restorecon -Rv /etc/pki/tls/certs/
```

6. Add the server certificate and private key to the **[authenticate.server]** section in the **/etc/tlshd.conf** file:

```
x509.certificate= /etc/pki/tls/certs/server.example.com.crt
x509.private_key= /etc/pki/tls/private/server.example.com.key
```

   Leave the **x509.truststore** parameter unset.

7. Enable and start the **tlshd** service:

```
# systemctl enable --now tlshd.service
```

Next steps

- Configuring an NFS client with TLS support

- Configuring an NFS client with mutual TLS support

4.10. CONFIGURING AN NFS CLIENT WITH TLS SUPPORT

Starting with Red Hat Enterprise Linux 9.6, you can configure the client by using the **xprtsec=tls** parameter to mount NFS with TLS support if the server supports NFS with TLS encryption.

Prerequisites

- You have configured the NFS server with TLS encryption. For details, see Configuring an NFS server with TLS support.
- You have installed the **ktls-utils** package.

Procedure

1. Import the Certificate Authority (CA) certificate to the systems's truststore:

```
# cp ca.crt /etc/pki/ca-trust/source/anchors
# update-ca-trust
```

2. Enable and start the **tlshd** service:

```
# systemctl enable --now tlshd.service
```

3. Mount an NFS share by using TLS encryption:

```
# mount -o xprtsec=tls server.example.com:/nfs/projects/ /mnt/
```

Verification

- Verify that the client successfully mounted NFS share with TLS support:

```
# journalctl -u tlshd
...
Apr 01 08:37:56 client.example.com tlshd[10688]: Handshake with server.example.com
(192.0.2.1) was successful
```

4.11. CONFIGURING AN NFS CLIENT WITH MUTUAL TLS SUPPORT

Starting with Red Hat Enterprise Linux 9.6, you can configure the NFS server and client to authenticate each other by using TLS protocol if the server supports NFS with TLS encryption.

Prerequisites

- You have configured the NFS server with TLS encryption. For details, see Configuring an NFS server with TLS support.
- You have installed the **ktls-utils** package.

Procedure

1. Create a private key and a certificate signing request (CSR):

```
# openssl req -new -newkey rsa:4096 -noenc \
-keyout /etc/pki/tls/private/client.example.com.key \
-out /etc/pki/tls/private/client.example.com.csr \
-subj "/C=US/ST=State/L=City/O=Organization/CN=client.example.com" \
-addext "subjectAltName=DNS:client.example.com,IP:192.0.2.2"
```

IMPORTANT

Common Name (CN) and DNS must match the hostname. IP must match IP of the host.

2. Send the **/etc/pki/tls/private/client.example.com.csr** file to a Certificate Authority (CA) and request a client certificate. Store the received CA certificate and the client certificate on the host.

3. Import the CA certificate to the systems's truststore:

```
# cp ca.crt /etc/pki/ca-trust/source/anchors
# update-ca-trust
```

4. Move the client certificate to the **/etc/pki/tls/certs/** directory:

```
# mv client.example.com.crt /etc/pki/tls/certs/
```

5. Ensure the SELinux context is correct on the private key and certificates:

```
# restorecon -Rv /etc/pki/tls/certs/
```

6. Add the client certificate and private key to the **[authenticate.client]** section in the **/etc/tlshd.conf** file:

```
x509.certificate= /etc/pki/tls/certs/client.example.com.crt
x509.private_key= /etc/pki/tls/private/client.example.com.key
```

Leave the **x509.truststore** parameter unset.

7. Enable and start the **tlshd** service:

```
# systemctl enable --now tlshd.service
```

8. Mount an NFS share by using TLS encryption:

```
# mount -o xprtsec=mtls server.example.com:/nfs/projects/ /mnt/
```

Verification

- Verify that the client successfully mounted NFS share with TLS support:

```
# journalctl -u tlshd
...
```

```
Apr 01 08:37:56 client.example.com tlshd[10688]: Handshake with server.example.com
(192.0.2.1) was successful
```

4.12. CONFIGURING GNOME TO STORE USER SETTINGS ON HOME DIRECTORIES HOSTED ON AN NFS SHARE

If you use GNOME on a system with home directories hosted on an NFS server, you must change the **keyfile** backend of the **dconf** database. Otherwise, **dconf** might not work correctly.

This change affects all users on the host because it changes how **dconf** manages user settings and configurations stored in the home directories.

Procedure

1. Add the following line to the beginning of the **/etc/dconf/profile/user** file. If the file does not exist, create it.

   ```
   service-db:keyfile/user
   ```

   With this setting, **dconf** polls the **keyfile** back end to determine whether updates have been made, so settings might not be updated immediately.

2. The changes take effect when the users logs out and in.

4.13. FREQUENTLY USED NFS MOUNT OPTIONS

The following are the commonly-used options when mounting NFS shares. You can use these options with **mount** commands, in **/etc/fstab** settings, and the **autofs** automapper.

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 **positive**.

nfsvers=*version*

Specifies which version of the NFS protocol to use, where version is **3**, **4**, **4.0**, **4.1**, or **4.2**. This is useful for hosts that run multiple NFS servers, or to disable retrying a mount with lower versions. If no version is specified, the client tries version **4.2** first, then negotiates down until it finds a version supported by the server.
The option **vers** is identical to **nfsvers**, and is included in this release for compatibility reasons.

noacl

Turns off all ACL processing. This can be needed when interfacing with old Red Hat Enterprise Linux versions that are not compatible with the recent ACL technology.

nolock

Disables file locking. This setting can be required when you connect to very old 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 the **set-user-identifier** and **set-group-identifier** bits. This prevents remote users from gaining higher privileges by running a **setuid** program.

retrans=*num*

The number of times the NFS client retries a request before it attempts further recovery action. If the **retrans** option is not specified, the NFS client tries each UDP request three times and each TCP request twice.

timeo=*num*

The time in tenths of a second the NFS client waits for a response before it retries an NFS request. For NFS over TCP, the default **timeo** value is 600 (60 seconds). The NFS client performs linear backoff: After each retransmission the timeout is increased by **timeo** up to the maximum of 600 seconds.

port=*num*

Specifies the numeric value of the NFS server port. For NFSv3, if num is **0** (the default value), or not specified, then mount queries the **rpcbind** service on the remote host for the port number to use. For NFSv4, if num is **0**, then mount queries the **rpcbind** service, but if it is not specified, the standard NFS port number of TCP 2049 is used instead and the remote **rpcbind** is not checked anymore.

rsize=*num* and **wsize=*num***

These options set the maximum number of bytes to be transferred in a single NFS read or write operation.
There is no fixed default value for **rsize** and **wsize**. By default, NFS uses the largest possible value that both the server and the client support. In Red Hat Enterprise Linux 9, the client and server maximum is 1,048,576 bytes. For more information, see the Red Hat Knowledgebase solution What are the default and maximum values for rsize and wsize with NFS mounts?.

sec=*options*

Security options to use for accessing files on the mounted export. The options value is a colon-separated list of one or more security options.
By default, the client attempts to find a security option that both the client and the server support. If the server does not support any of the selected options, the mount operation fails.

Available options:

- **sec=sys** 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.

Additional resources

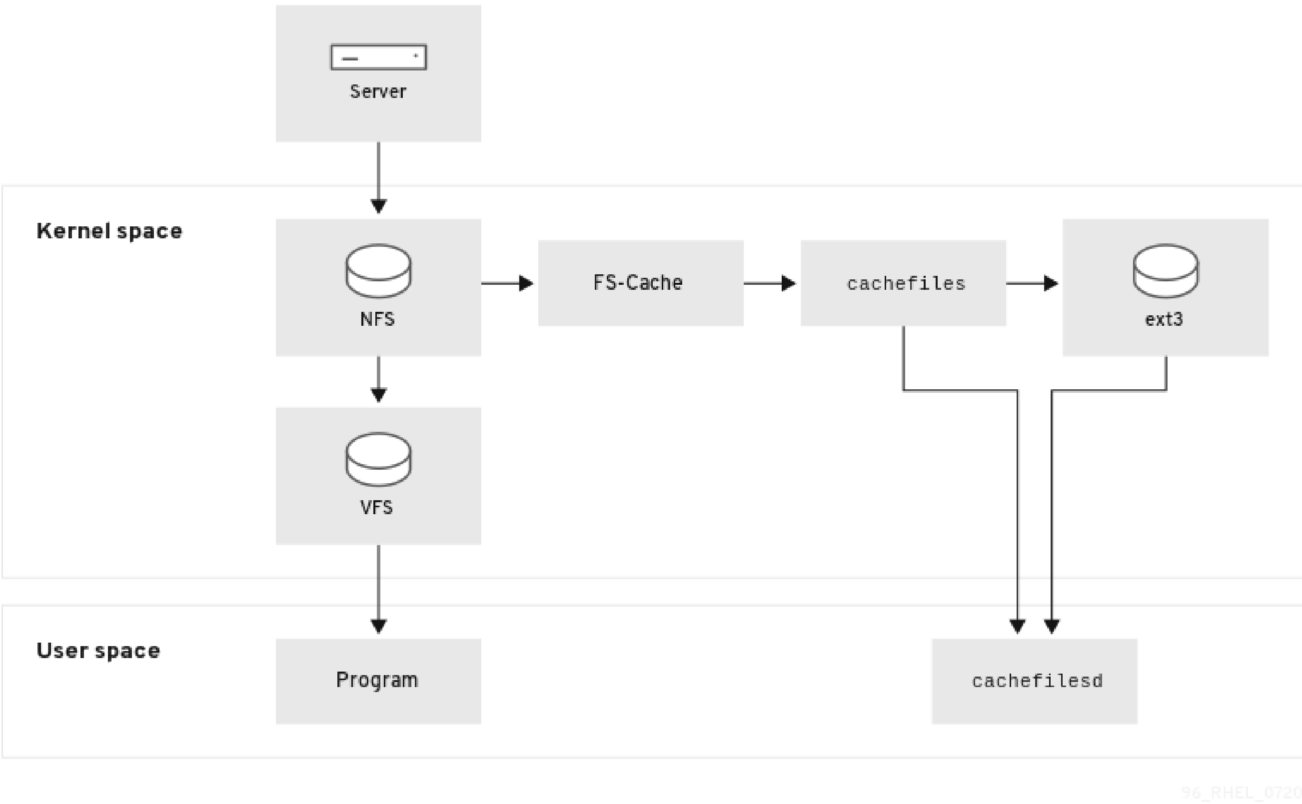
- **mount(8)** and `nfs(5)` man pages on your system

4.14. ENABLING CLIENT-SIDE CACHING OF NFS CONTENT

FS-Cache is a persistent local cache on the client that file systems can use to take data retrieved from over the network and cache it on the local disk. This helps to minimize network traffic.

4.14.1. How NFS caching works

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



FS-Cache is designed to be as transparent as possible to the users and administrators of a system. FS-Cache allows a file system on a server to interact directly with a client's local cache without creating an over-mounted file system. With NFS, a mount option instructs the client to mount the NFS share with FS-cache enabled. The mount point will cause automatic upload for two kernel modules: **fscache** and **cachefiles**. The **cachefilesd** daemon communicates with the kernel modules to implement the cache.

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 example, a client can still mount an NFS share whether or not FS-Cache is enabled. In addition, cached NFS can handle files that will not 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, the **cachefiles** service. FS-Cache requires a mounted block-based file system, that supports block mapping (**bmap**) and extended attributes as its cache back end:

- XFS
- ext3
- ext4

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 or 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.

Using FS-Cache is a compromise between various factors. If FS-Cache is being used to cache NFS traffic, it may slow the client down, but can massively reduce the network and server loading by satisfying read requests locally without consuming network bandwidth.

4.14.2. Installing and configuring the cachefilesd service

Red Hat Enterprise Linux provides only the **cachefiles** caching back end. The **cachefilesd** service initiates and manages **cachefiles**. The **/etc/cachefilesd.conf** file controls how **cachefiles** provides caching services.

Prerequisites

- The file system mounted under the **/var/cache/fscache/** directory is **ext3**, **ext4**, or **xfs**.
- The file system mounted under **/var/cache/fscache/** uses extended attributes, which is the default if you created the file system on RHEL 8 or later.

Procedure

1. Install the **cachefilesd** package:

```
# dnf install cachefilesd
```

2. Enable and start the **cachefilesd** service:

```
# systemctl enable --now cachefilesd
```

Verification

1. Mount an NFS share with the **fsc** option to use the cache:

   a. To mount a share temporarily, enter:

   ```
   # mount -o fsc server.example.com:/nfs/projects/ /mnt/
   ```

   b. To mount a share permanently, add the **fsc** option to the entry in the **/etc/fstab** file:

   ```
   <nfs_server_ip_or_hostname>:/<exported_share>     <mount point>    nfs fsc 0 0
   ```

2. Display the FS-cache statistics:

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

Additional resources

- **/usr/share/doc/cachefilesd/README** file

- **/usr/share/doc/kernel-doc-<kernel_version>/Documentation/filesystems/caching/fscache.rst** provided by the **kernel-doc** package

4.14.3. Sharing NFS cache

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; a uniquifier string
- Level 3: File Handle
- Level 4: Page number in file

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

Example 4.1. NFS cache sharing:

The following two mounts likely share the superblock as they have the same mount options, especially if because they come from the same partition on the NFS server:

```
# mount -o fsc home0:/nfs/projects /projects
# mount -o fsc home0:/nfs/home /home/
```

If the mount options are different, they do not share the superblock:

```
# mount -o fsc,rsize=8192 home0:/nfs/projects /projects
# mount -o fsc,rsize=65536 home0:/nfs/home /home/
```

NOTE

The user cannot share caches between superblocks that have different communications or protocol parameters. For example, it is not possible to share caches between NFSv4.0 and NFSv3 or between NFSv4.1 and NFSv4.2 because they force different superblocks. Also setting parameters, such as the read size (**rsize**), prevents cache sharing because, again, it forces a different superblock.

4.14.4. NFS cache limitations

There are some cache limitations with NFS:

- Opening a file from a shared file system for direct I/O automatically bypasses the cache. This is because this type of access must be direct to the server.
- Opening a file from a shared file system for either direct I/O or writing flushes 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.

4.14.5. How cache culling works

The **cachefilesd** service works by caching remote data from shared file systems to free space on the local disk. This could potentially consume all available free space, which could cause problems if the disk also contains the root partition. To control this, **cachefilesd** tries to maintain a certain amount of free space by discarding old objects, such as less-recently accessed objects, 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 settings in **/etc/cachefilesd.conf** which control six limits:

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; the user cannot treat them separately.

CHAPTER 5. MOUNTING AN SMB SHARE

The Server Message Block (SMB) protocol implements an application-layer network protocol used to access resources on a server, such as file shares and shared printers.

> **NOTE**
>
> In the context of SMB, you can find mentions about the Common Internet File System (CIFS) protocol, which is a dialect of SMB. Both the SMB and CIFS protocol are supported, and the kernel module and utilities involved in mounting SMB and CIFS shares both use the name **cifs**.

The **cifs-utils** package provides utilities to:

- Mount SMB and CIFS shares
- Manage NT LAN Manager (NTLM) credentials in the kernel's keyring
- Set and display Access Control Lists (ACL) in a security descriptor on SMB and CIFS shares

5.1. SUPPORTED SMB PROTOCOL VERSIONS

The **cifs.ko** kernel module supports the following SMB protocol versions:

- SMB 1

> **WARNING**
>
> The SMB1 protocol is deprecated due to known security issues, and is only **safe to use on a private network** The main reason that SMB1 is still provided as a supported option is that currently it is the only SMB protocol version that supports UNIX extensions. If you do not need to use UNIX extensions on SMB, Red Hat strongly recommends using SMB2 or later.

- SMB 2.0
- SMB 2.1
- SMB 3.0
- SMB 3.1.1

> **NOTE**
>
> Depending on the protocol version, not all SMB features are implemented.

5.2. UNIX EXTENSIONS SUPPORT

Samba uses the **CAP_UNIX** capability bit in the SMB protocol to provide the UNIX extensions feature. These extensions are also supported by the **cifs.ko** kernel module. However, both Samba and the kernel module support UNIX extensions only in the SMB 1 protocol.

Prerequisites

- The **cifs-utils** package is installed.

Procedure

1. Set the **server min protocol** parameter in the **[global]** section in the **/etc/samba/smb.conf** file to **NT1**.

2. Mount the share using the SMB 1 protocol by providing the **-o vers=1.0** option to the mount command. For example:

```
# mount -t cifs -o vers=1.0,username=<user_name> //<server_name>/<share_name>
/mnt/
```

   By default, the kernel module uses SMB 2 or the highest later protocol version supported by the server. Passing the **-o vers=1.0** option to the **mount** command forces that the kernel module uses the SMB 1 protocol that is required for using UNIX extensions.

Verification

- Display the options of the mounted share:

```
# mount
...
//<server_name>/<share_name> on /mnt type cifs (...,unix,...)
```

  If the **unix** entry is displayed in the list of mount options, UNIX extensions are enabled.

5.3. MANUALLY MOUNTING AN SMB SHARE

If you only require an SMB share to be temporary mounted, you can mount it manually using the **mount** utility.

> **NOTE**
>
> Manually mounted shares are not mounted automatically again when you reboot the system. To configure that Red Hat Enterprise Linux automatically mounts the share when the system boots, see Mounting an SMB share automatically when the system boots .

Prerequisites

- The **cifs-utils** package is installed.

Procedure

- Use the **mount** utility with the **-t cifs** parameter to mount an SMB share:

```
# mount -t cifs -o username=<user_name> //<server_name>/<share_name> /mnt/
Password for <user_name>@//<server_name>/<share_name>:  password
```

In the **-o** parameter, you can specify options that are used to mount the share. For details, see the **OPTIONS** section in the **mount.cifs(8)** man page and Frequently used mount options.

Example 5.1. Mounting a share using an encrypted SMB 3.0 connection

To mount the **server****example**\ share as the ***DOMAIN*****Administrator** user over an encrypted SMB 3.0 connection into the **/mnt/** directory:

```
# mount -t cifs -o username=DOMAIN\Administrator,seal,vers=3.0 //server/example
/mnt/
Password for DOMAIN\Administrator@//server_name/share_name:  password
```

Verification

- List the content of the mounted share:

```
# ls -l /mnt/
total 4
drwxr-xr-x.  2 root root 8748 Dec  4 16:27 test.txt
drwxr-xr-x. 17 root root 4096 Dec  4 07:43 Demo-Directory
```

5.4. MOUNTING AN SMB SHARE AUTOMATICALLY WHEN THE SYSTEM BOOTS

If access to a mounted SMB share is permanently required on a server, mount the share automatically at boot time.

Prerequisites

- The **cifs-utils** package is installed.

Procedure

1. Add an entry for the share to the **/etc/fstab** file. For example:

```
//<server_name>/<share_name>  /mnt  cifs  credentials=/root/smb.cred  0 0
```

IMPORTANT

To enable the system to mount a share automatically, you must store the user name, password, and domain name in a credentials file. For details, see Creating a credentials file to authenticate to an SMB share

In the fourth field of the row in the **/etc/fstab**, specify mount options, such as the path to the credentials file. For details, see the **OPTIONS** section in the **mount.cifs(8)** man page and Frequently used mount options.

Verification

- Mount the share by specifying the mount point:

```
# mount /mnt/
```

5.5. CREATING A CREDENTIALS FILE TO AUTHENTICATE TO AN SMB SHARE

In certain situations, such as when mounting a share automatically at boot time, a share should be mounted without entering the user name and password. To implement this, create a credentials file.

Prerequisites

- The **cifs-utils** package is installed.

Procedure

1. Create a file, such as **/root/smb.cred**, and specify the user name, password, and domain name that file:

```
username=user_name
password=password
domain=domain_name
```

2. Set the permissions to only allow the owner to access the file:

```
# chown user_name /root/smb.cred
# chmod 600 /root/smb.cred
```

You can now pass the **credentials=*file_name*** mount option to the **mount** utility or use it in the **/etc/fstab** file to mount the share without being prompted for the user name and password.

5.6. PERFORMING A MULTI-USER SMB MOUNT

The credentials you provide to mount a share determine the access permissions on the mount point by default. For example, if you use the ***DOMAIN*\example** user when you mount a share, all operations on the share will be executed as this user, regardless which local user performs the operation.

However, in certain situations, the administrator wants to mount a share automatically when the system boots, but users should perform actions on the share's content using their own credentials. The **multiuser** mount options lets you configure this scenario.

> **IMPORTANT**
>
> To use the **multiuser** mount option, you must additionally set the **sec** mount option to a security type that supports providing credentials in a non-interactive way, such as **krb5** or the **ntlmssp** option with a credentials file. For details, see Accessing a share as a user .

The **root** user mounts the share using the **multiuser** option and an account that has minimal access to the contents of the share. Regular users can then provide their user name and password to the current session's kernel keyring using the **cifscreds** utility. If the user accesses the content of the mounted share, the kernel uses the credentials from the kernel keyring instead of the one initially used to mount the share.

Using this feature consists of the following steps:

- Mount a share with the **multiuser** option.
- Optionally, verify if the share was successfully mounted with the **multiuser** option.
- Access the share as a user .

Prerequisites

- The **cifs-utils** package is installed.

5.6.1. Mounting a share with the multiuser option

Before users can access the share with their own credentials, mount the share as the **root** user using an account with limited permissions.

Procedure

To mount a share automatically with the **multiuser** option when the system boots:

1. Create the entry for the share in the **/etc/fstab** file. For example:

```
//server_name/share_name  /mnt  cifs  multiuser,sec=ntlmssp,credentials=/root/smb.cred
0 0
```

2. Mount the share:

```
# mount /mnt/
```

If you do not want to mount the share automatically when the system boots, mount it manually by passing **-o multiuser,sec=security_type** to the **mount** command. For details about mounting an SMB share manually, see Manually mounting an SMB share .

5.6.2. Verifying if an SMB share is mounted with the multiuser option

To verify if a share is mounted with the **multiuser** option, display the mount options.

Procedure

```
# mount
...
//server_name/share_name on /mnt type cifs (sec=ntlmssp,multiuser,...)
```

If the **multiuser** entry is displayed in the list of mount options, the feature is enabled.

5.6.3. Accessing a share as a user

If an SMB share is mounted with the **multiuser** option, users can provide their credentials for the server to the kernel's keyring:

–

```
# cifscreds add -u SMB_user_name server_name
Password: password
```

When the user performs operations in the directory that contains the mounted SMB share, the server applies the file system permissions for this user, instead of the one initially used when the share was mounted.

> **NOTE**
>
> Multiple users can perform operations using their own credentials on the mounted share at the same time.

5.7. FREQUENTLY USED SMB MOUNT OPTIONS

When you mount an SMB share, the mount options determine:

- How the connection will be established with the server. For example, which SMB protocol version is used when connecting to the server.
- How the share will be mounted into the local file system. For example, if the system overrides the remote file and directory permissions to enable multiple local users to access the content on the server.

To set multiple options in the fourth field of the **/etc/fstab** file or in the **-o** parameter of a mount command, separate them with commas. For example, see Mounting a share with the multiuser option .

The following list gives frequently used mount options:

Option	Description
credentials=*file_name*	Sets the path to the credentials file. See Authenticating to an SMB share using a credentials file.
dir_mode=*mode*	Sets the directory mode if the server does not support CIFS UNIX extensions.
file_mode=*mode*	Sets the file mode if the server does not support CIFS UNIX extensions.
password=*password*	Sets the password used to authenticate to the SMB server. Alternatively, specify a credentials file using the **credentials** option.
seal	Enables encryption support for connections using SMB 3.0 or a later protocol version. Therefore, use **seal** together with the **vers** mount option set to **3.0** or later. See the example in Manually mounting an SMB share.

Option	Description
sec=*security_mode*	Sets the security mode, such as **ntlmsspi**, to enable NTLMv2 password hashing and enabled packet signing. For a list of supported values, see the option's description in the **mount.cifs(8)** man page on your system. If the server does not support the **ntlmv2** security mode, use **sec=ntlmssp**, which is the default. For security reasons, do not use the insecure **ntlm** security mode.
username=*user_name*	Sets the user name used to authenticate to the SMB server. Alternatively, specify a credentials file using the **credentials** option.
vers=*SMB_protocol_version*	Sets the SMB protocol version used for the communication with the server.

For a complete list, see the **OPTIONS** section in the **mount.cifs(8)** man page on your system.

CHAPTER 6. OVERVIEW OF PERSISTENT NAMING ATTRIBUTES

As a system administrator, you need to refer to storage volumes using persistent naming attributes to build storage setups that are reliable over multiple system boots.

6.1. DISADVANTAGES OF NON-PERSISTENT NAMING ATTRIBUTES

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.

Traditionally, non-persistent names in the form of **/dev/sd*(major number)(minor number)*** are used on Linux to refer to storage devices. 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.

Such a change in the ordering might occur in the following situations:

- The parallelization of the system boot process detects storage devices in a different order with each system boot.
- A disk fails to power up or respond to the SCSI controller. This results in it not being detected by the normal device probe. The disk is not accessible to the system and subsequent devices will have their major and minor number range, including the associated **sd** names shifted down. For example, if 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) fails to initialize, causing all disks connected to that HBA to not be detected. Any disks connected to subsequently probed HBAs are assigned different major and minor number ranges, and different associated **sd** names.
- The order of driver initialization changes if different types of HBAs are present in the system. This causes the disks connected to those HBAs to be detected in a different order. This might 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 might 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 does not cause the major and minor number ranges, and the associated **sd** names to be reserved; it only provides consistent SCSI target ID numbers.

These reasons make it undesirable 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 might result.

Occasionally, 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.

6.2. FILE SYSTEM AND DEVICE IDENTIFIERS

File system identifiers are tied to the file system itself, while device identifiers are linked to the physical block device. Understanding the difference is important for proper storage management.

File system identifiers

File system identifiers are tied to a particular file system created on a block device. The identifier is also stored as part of the file system. If you copy the file system to a different device, it still carries the same file system identifier. However, if you rewrite the device, such as by formatting it with the **mkfs** utility, the device loses the attribute.

File system identifiers include:

- Unique identifier (UUID)
- Label

Device identifiers

Device identifiers are tied to a block device: for example, a disk or a partition. If you rewrite the device, such as by formatting it with the **mkfs** utility, the device keeps the attribute, because it is not stored in the file system.

Device identifiers include:

- World Wide Identifier (WWID)
- Partition UUID
- Serial number

Recommendations

- Some file systems, such as logical volumes, span multiple devices. Red Hat recommends accessing these file systems using file system identifiers rather than device identifiers.

6.3. DEVICE NAMES MANAGED BY THE UDEV MECHANISM IN /DEV/DISK/

The **udev** mechanism is used for all types of devices in Linux, and is not limited only for storage devices. It provides different kinds of persistent naming attributes in the **/dev/disk/** directory. In the case of storage devices, Red Hat Enterprise Linux contains **udev** rules that create symbolic links in the **/dev/disk/** directory. This enables you to refer to storage devices by:

- Their content
- A unique identifier
- Their serial number.

Although **udev** naming attributes are persistent, in that they do not change on their own across system reboots, some are also configurable.

6.3.1. File system identifiers

The UUID attribute in /dev/disk/by-uuid/

Entries in this directory provide a symbolic name that refers to the storage device by a **unique identifier** (UUID) in the content (that is, the data) stored on the device. For example:

```
/dev/disk/by-uuid/3e6be9de-8139-11d1-9106-a43f08d823a6
```

You can use the UUID to refer to the device in the **/etc/fstab** file using the following syntax:

```
UUID=3e6be9de-8139-11d1-9106-a43f08d823a6
```

You can configure the UUID attribute when creating a file system, and you can also change it later on.

The Label attribute in /dev/disk/by-label/

Entries in this directory provide a symbolic name that refers to the storage device by a **label** in the content (that is, the data) stored on the device.

For example:

```
/dev/disk/by-label/Boot
```

You can use the label to refer to the device in the **/etc/fstab** file using the following syntax:

```
LABEL=Boot
```

You can configure the Label attribute when creating a file system, and you can also change it later on.

6.3.2. Device identifiers

The WWID attribute in /dev/disk/by-id/

The World Wide Identifier (WWID) is a persistent, **system-independent identifier** 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. The identifier is a property of the device but is not stored in the content (that is, the data) on the devices.

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**).

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.

> **NOTE**
>
> If your are using an NVMe device, you might run into a disk by-id naming change for some vendors, if the serial number of your device has leading whitespace.

Example 6.1. WWID mappings

WWID symlink	Non-persistent device	Note
/dev/disk/by-id/scsi-3600508b400105e210000900000490000	**/dev/sda**	A device with a page **0x83** identifier

WWID symlink	Non-persistent device	Note
/dev/disk/by-id/scsi-SSEAGATE_ST373453LW_3HW1RHM6	**/dev/sdb**	A device with a page **0x80** identifier
/dev/disk/by-id/ata-SAMSUNG_MZNLN256HMHQ-000L7_S2WDNX0J336519-part3	**/dev/sdc3**	A disk partition

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.

The Partition UUID attribute in /dev/disk/by-partuuid

The Partition UUID (PARTUUID) attribute identifies partitions as defined by GPT partition table.

Example 6.2. Partition UUID mappings

PARTUUID symlink	Non-persistent device
/dev/disk/by-partuuid/4cd1448a-01	**/dev/sda1**
/dev/disk/by-partuuid/4cd1448a-02	**/dev/sda2**
/dev/disk/by-partuuid/4cd1448a-03	**/dev/sda3**

The Path attribute in /dev/disk/by-path/

This attribute provides a symbolic name that refers to the storage device by the **hardware path** used to access the device.

The Path attribute fails if any part of the hardware path (for example, the PCI ID, target port, or LUN number) changes. The Path attribute is therefore unreliable. However, the Path attribute may be useful in one of the following scenarios:

- You need to identify a disk that you are planning to replace later.
- You plan to install a storage service on a disk in a specific location.

6.4. THE WORLD WIDE IDENTIFIER WITH DM MULTIPATH

You can configure Device Mapper (DM) Multipath to map between the World Wide Identifier (WWID) and non-persistent device names.

If there are multiple paths from a system to a device, DM Multipath uses the WWID to detect this. DM Multipath then presents a single "pseudo-device" in the **/dev/mapper/wwid** directory, such as **/dev/mapper/3600508b400105df70000e00000ac0000**.

The command **multipath -l** shows the mapping to the non-persistent identifiers:

- ***Host*:*Channel*:*Target*:*LUN***
- **/dev/sd** name
- ***major*:*minor*** number

Example 6.3. WWID mappings in a multipath configuration

An example output of the **multipath -l** command:

```
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]
```

DM 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 DM 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 **mpath*N*** 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.

6.5. LIMITATIONS OF THE UDEV DEVICE NAMING CONVENTION

The following are some limitations of the **udev** naming convention:

- It is possible that the device might not be accessible at the time the query is performed because the **udev** mechanism might 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 might 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 might 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** service takes some amount of time to process the rules for each one. This might 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 might open the device for a brief period of time, making the device inaccessible for other uses.

- The device names managed by the **udev** mechanism in /dev/disk/ may change between major releases, requiring you to update the links.

6.6. LISTING PERSISTENT NAMING ATTRIBUTES

You can find out the persistent naming attributes of non-persistent storage devices.

Procedure

- To list the UUID and Label attributes, use the **lsblk** utility:

```
$ lsblk --fs storage-device
```

For example:

Example 6.4. Viewing the UUID and Label of a file system

```
$ lsblk --fs /dev/sda1

NAME FSTYPE LABEL UUID                                 MOUNTPOINT
sda1 xfs    Boot  afa5d5e3-9050-48c3-acc1-bb30095f3dc4 /boot
```

- To list the PARTUUID attribute, use the **lsblk** utility with the **--output +PARTUUID** option:

```
$ lsblk --output +PARTUUID
```

For example:

Example 6.5. Viewing the PARTUUID attribute of a partition

```
$ lsblk --output +PARTUUID /dev/sda1

NAME MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT PARTUUID
sda1   8:1    0  512M  0 part /boot      4cd1448a-01
```

- To list the WWID attribute, examine the targets of symbolic links in the **/dev/disk/by-id/** directory. For example:

Example 6.6. Viewing the WWID of all storage devices on the system

```
$ file /dev/disk/by-id/*

/dev/disk/by-id/ata-QEMU_HARDDISK_QM00001
symbolic link to ../../sda
/dev/disk/by-id/ata-QEMU_HARDDISK_QM00001-part1
symbolic link to ../../sda1
/dev/disk/by-id/ata-QEMU_HARDDISK_QM00001-part2
symbolic link to ../../sda2
/dev/disk/by-id/dm-name-rhel_rhel8-root
symbolic link to ../../dm-0
/dev/disk/by-id/dm-name-rhel_rhel8-swap
```

```
symbolic link to ../../dm-1
/dev/disk/by-id/dm-uuid-LVM-
QIWtEHtXGobe5bewlIUDivKOz5ofkgFhP0RMFsNyySVihqEl2cWWbR7MjXJolD6g
symbolic link to ../../dm-1
/dev/disk/by-id/dm-uuid-LVM-
QIWtEHtXGobe5bewlIUDivKOz5ofkgFhXqH2M45hD2H9nAf2qfWSrlRLhzfMyOKd
symbolic link to ../../dm-0
/dev/disk/by-id/lvm-pv-uuid-atlr2Y-vuMo-ueoH-CpMG-4JuH-AhEF-wu4QQm
symbolic link to ../../sda2
```

6.7. MODIFYING PERSISTENT NAMING ATTRIBUTES

You can change the UUID or Label persistent naming attribute of a file system.

NOTE

Changing **udev** attributes happens in the background and might take a long time. The **udevadm settle** command waits until the change is fully registered, which ensures that your next command will be able to use the new attribute correctly.

In the following commands:

- Replace *new-uuid* with the UUID you want to set; for example, **1cdfbc07-1c90-4984-b5ec-f61943f5ea50**. You can generate a UUID using the **uuidgen** command.
- Replace *new-label* with a label; for example, **backup_data**.

Prerequisites

- If you are modifying the attributes of an XFS file system, unmount it first.

Procedure

- To change the UUID or Label attributes of an **XFS** file system, use the **xfs_admin** utility:

```
# xfs_admin -U new-uuid -L new-label storage-device
# udevadm settle
```

- To change the UUID or Label attributes of an **ext4**, **ext3**, or **ext2** file system, use the **tune2fs** utility:

```
# tune2fs -U new-uuid -L new-label storage-device
# udevadm settle
```

- To change the UUID or Label attributes of a swap volume, use the **swaplabel** utility:

```
# swaplabel --uuid new-uuid --label new-label swap-device
# udevadm settle
```

CHAPTER 7. PARTITION OPERATIONS WITH PARTED

parted is a program to manipulate disk partitions. It supports multiple partition table formats, including MS-DOS and GPT. It is useful for creating space for new operating systems, reorganizing disk usage, and copying data to new hard disks.

7.1. VIEWING THE PARTITION TABLE WITH PARTED

Display the partition table of a block device to see the partition layout and details about individual partitions. You can view the partition table on a block device using the **parted** utility.

Procedure

1. Start the **parted** utility. For example, the following output lists the device **/dev/sda**:

```
# parted /dev/sda
```

2. View the partition table:

```
(parted) print

Model: ATA SAMSUNG MZNLN256 (scsi)
Disk /dev/sda: 256GB
Sector size (logical/physical): 512B/512B
Partition Table: msdos
Disk Flags:

Number  Start   End     Size    Type      File system  Flags
 1      1049kB  269MB   268MB   primary   xfs          boot
 2      269MB   34.6GB  34.4GB  primary
 3      34.6GB  45.4GB  10.7GB  primary
 4      45.4GB  256GB   211GB   extended
 5      45.4GB  256GB   211GB   logical
```

3. Optional: Switch to the device you want to examine next:

```
(parted) select block-device
```

For a detailed description of the print command output, see the following:

Model: ATA SAMSUNG MZNLN256 (scsi)

The disk type, manufacturer, model number, and interface.

Disk /dev/sda: 256GB

The file path to the block device and the storage capacity.

Partition Table: msdos

The disk label type.

Number

The partition number. For example, the partition with minor number 1 corresponds to **/dev/sda1**.

Start and **End**

The location on the device where the partition starts and ends.

Type

Valid types are metadata, free, primary, extended, or logical.

File system

The file system type. If the **File system** field of a device shows no value, this means that its file system type is unknown. The **parted** utility cannot recognize the file system on encrypted devices.

Flags

Lists the flags set for the partition. Available flags are **boot**, **root**, **swap**, **hidden**, **raid**, **lvm**, or **lba**.

Additional resources

- **parted(8)** man page on your system

7.2. CREATING A PARTITION TABLE ON A DISK WITH PARTED

Use the **parted** utility to format a block device with a partition table more easily.

> **WARNING**
>
> Formatting a block device with a partition table deletes all data stored on the device.

Procedure

1. Start the interactive **parted** shell:

   ```
   # parted block-device
   ```

2. Determine if there already is a partition table on the device:

   ```
   (parted) print
   ```

   If the device already contains partitions, they will be deleted in the following steps.

3. Create the new partition table:

   ```
   (parted) mklabel table-type
   ```

   - Replace *table-type* with with the intended partition table type:
     - **msdos** for MBR
     - **gpt** for GPT

   Example 7.1. Creating a GUID Partition Table (GPT) table

   To create a GPT table on the disk, use:

```
(parted) mklabel gpt
```

The changes start applying after you enter this command.

4. View the partition table to confirm that it is created:

```
(parted) print
```

5. Exit the **parted** shell:

```
(parted) quit
```

Additional resources

- **parted(8)** man page on your system

7.3. CREATING A PARTITION WITH PARTED

As a system administrator, you can create new partitions on a disk by using the **parted** utility.

> **NOTE**
>
> The required partitions are **swap**, /**boot**/, and / **(root)**.

Prerequisites

- A partition table on the disk.
- If the partition you want to create is larger than 2TiB, format the disk with the **GUID Partition Table (GPT)**.

Procedure

1. Start the **parted** utility:

```
# parted block-device
```

2. View the current partition table to determine if there is enough free space:

```
(parted) print
```

- Resize the partition in case there is not enough free space.
- From the partition table, determine:
  - The start and end points of the new partition.
  - On MBR, what partition type it should be.

3. Create the new partition:

```
(parted) mkpart part-type name fs-type start end
```

- Replace *part-type* with with **primary**, **logical**, or **extended**. This applies only to the MBR partition table.
- Replace *name* with an arbitrary partition name. This is required for GPT partition tables.
- Replace *fs-type* with **xfs**, **ext2**, **ext3**, **ext4**, **fat16**, **fat32**, **hfs**, **hfs+**, **linux-swap**, **ntfs**, or **reiserfs**. The *fs-type* parameter is optional. Note that the **parted** utility does not create the file system on the partition.
- Replace *start* and *end* with the sizes that determine the starting and ending points of the partition, counting from the beginning of the disk. You can use size suffixes, such as **512MiB**, **20GiB**, or **1.5TiB**. The default size is in megabytes.

Example 7.2. Creating a small primary partition

To create a primary partition from 1024MiB until 2048MiB on an MBR table, use:

```
(parted) mkpart primary 1024MiB 2048MiB
```

The changes start applying after you enter the command.

4. View the partition table to confirm that the created partition is in the partition table with the correct partition type, file system type, and size:

```
(parted) print
```

5. Exit the **parted** shell:

```
(parted) quit
```

6. Register the new device node:

```
# udevadm settle
```

7. Verify that the kernel recognizes the new partition:

```
# cat /proc/partitions
```

Additional resources

- **parted(8)** man page on your system
- Creating a partition table on a disk with parted
- Resizing a partition with parted

7.4. REMOVING A PARTITION WITH PARTED

Using the **parted** utility, you can remove a disk partition to free up disk space.

Procedure

1. Start the interactive **parted** shell:

```
# parted block-device
```

   - Replace *block-device* with the path to the device where you want to remove a partition: for example, **/dev/sda**.

2. View the current partition table to determine the minor number of the partition to remove:

```
(parted) print
```

3. Remove the partition:

```
(parted) rm minor-number
```

   - Replace *minor-number* with the minor number of the partition you want to remove.

   The changes start applying as soon as you enter this command.

4. Verify that you have removed the partition from the partition table:

```
(parted) print
```

5. Exit the **parted** shell:

```
(parted) quit
```

6. Verify that the kernel registers that the partition is removed:

```
# cat /proc/partitions
```

7. Remove the partition from the **/etc/fstab** file, if it is present. Find the line that declares the removed partition, and remove it from the file.

8. Regenerate mount units so that your system registers the new **/etc/fstab** configuration:

```
# systemctl daemon-reload
```

9. If you have deleted a swap partition or removed pieces of LVM, remove all references to the partition from the kernel command line:

   a. List active kernel options and see if any option references the removed partition:

   ```
   # grubby --info=ALL
   ```

   b. Remove the kernel options that reference the removed partition:

   ```
   # grubby --update-kernel=ALL --remove-args="option"
   ```

10. To register the changes in the early boot system, rebuild the **initramfs** file system:

```
# dracut --force --verbose
```

Additional resources

- **parted(8)** man page on your system

7.5. RESIZING A PARTITION WITH PARTED

Using the **parted** utility, extend a partition to use unused disk space, or shrink a partition to use its capacity for different purposes.

Prerequisites

- Back up the data before shrinking a partition.
- If the partition you want to create is larger than 2TiB, format the disk with the **GUID Partition Table (GPT)**.
- If you want to shrink the partition, first shrink the file system so that it is not larger than the resized partition.

> **NOTE**
>
> XFS does not support shrinking.

Procedure

1. Start the **parted** utility:

   ```
   # parted block-device
   ```

2. View the current partition table:

   ```
   (parted) print
   ```

   From the partition table, determine:

   - The minor number of the partition.
   - The location of the existing partition and its new ending point after resizing.

3. Resize the partition:

   ```
   (parted) resizepart 1 2GiB
   ```

   - Replace *1* with the minor number of the partition that you are resizing.
   - Replace *2* with the size that determines the new ending point of the resized partition, counting from the beginning of the disk. You can use size suffixes, such as **512MiB**, **20GiB**, or **1.5TiB**. The default size is in megabytes.

4. View the partition table to confirm that the resized partition is in the partition table with the correct size:

```
(parted) print
```

5. Exit the **parted** shell:

```
(parted) quit
```

6. Verify that the kernel registers the new partition:

```
# cat /proc/partitions
```

7. Optional: If you extended the partition, extend the file system on it as well.

Additional resources

- **parted(8)** man page on your system

CHAPTER 8. STRATEGIES FOR REPARTITIONING A DISK

There are different approaches to repartitioning a disk. These include:

- Unpartitioned free space is available.
- An unused partition is available.
- Free space in an actively used partition is available.

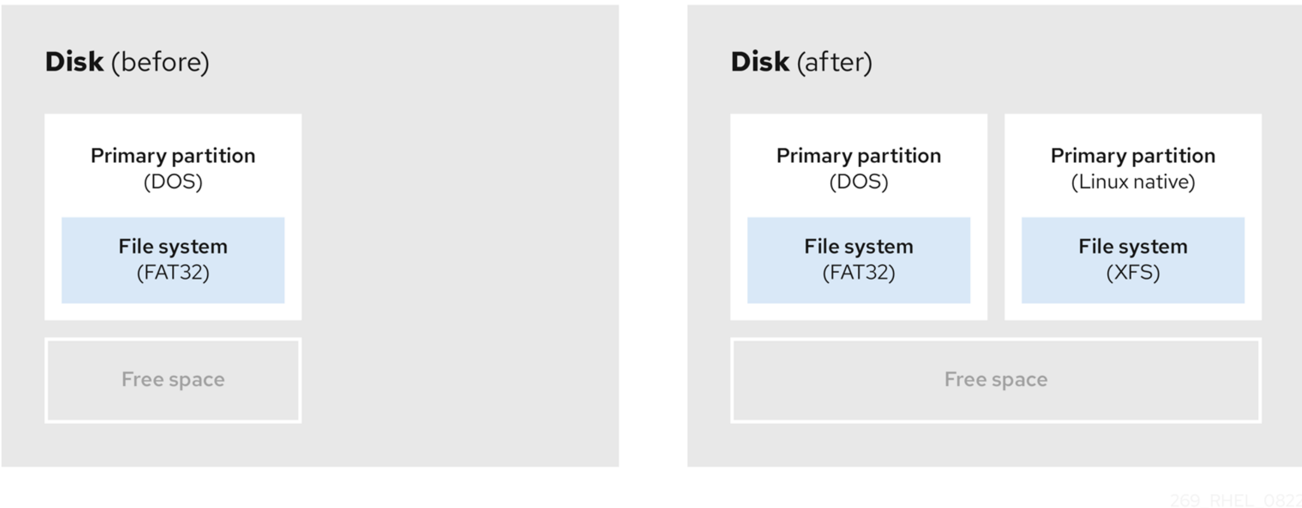
NOTE

The following examples are simplified for clarity and do not reflect the exact partition layout when actually installing Red Hat Enterprise Linux.

8.1. USING UNPARTITIONED FREE SPACE

Partitions that are already defined and do not span the entire hard disk, leave unallocated space that is not part of any defined partition. The following diagram shows what this might look like.

Figure 8.1. Disk with unpartitioned free space



The first diagram represents a disk with one primary partition and an undefined partition with unallocated space. The second diagram represents a disk with two defined partitions with allocated space.

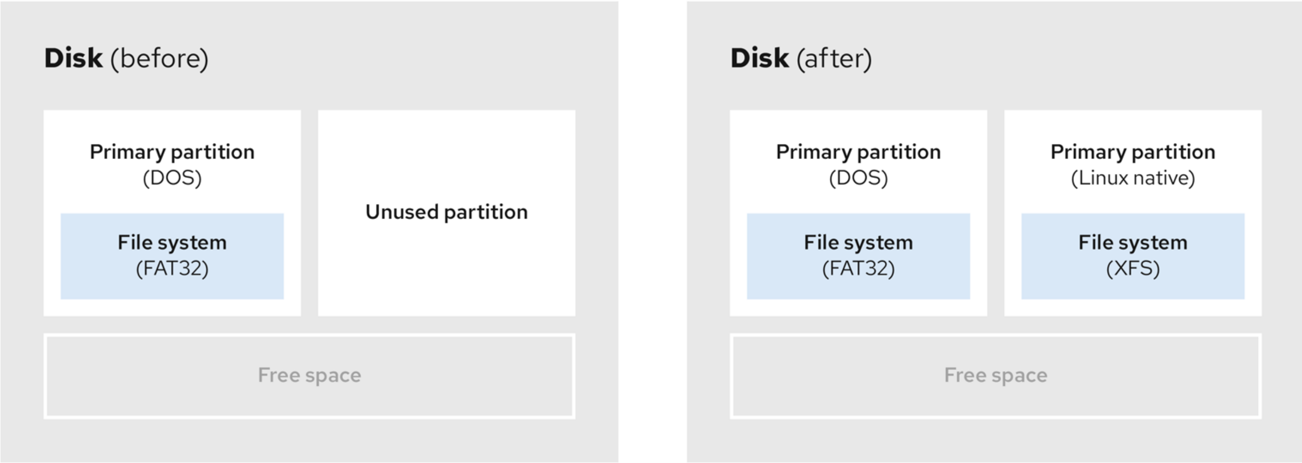
An unused hard disk also falls into this category. The only difference is that *all* the space is not part of any defined partition.

On a new disk, you can create the necessary partitions from the unused space. Most preinstalled operating systems are configured to take up all available space on a disk drive.

8.2. USING SPACE FROM AN UNUSED PARTITION

In the following example, the first diagram represents a disk with an unused partition. The second diagram represents reallocating an unused partition for Linux.

Figure 8.2. Disk with an unused partition



To use the space allocated to the unused partition, delete the partition and then create the appropriate Linux partition instead. Alternatively, during the installation process, delete the unused partition and manually create new partitions.

8.3. USING FREE SPACE FROM AN ACTIVE PARTITION

This process can be difficult to manage because an active partition, that is already in use, contains the required free space. In most cases, hard disks of computers with preinstalled software contain one larger partition holding the operating system and data.

> **WARNING**
>
> If you want to use an operating system (OS) on an active partition, you must reinstall the OS. Be aware that some computers, which include pre-installed software, do not include installation media to reinstall the original OS. Check whether this applies to your OS before you destroy an original partition and the OS installation.

To optimise the use of available free space, you can use the methods of destructive or non-destructive repartitioning.

8.3.1. Destructive repartitioning

Destructive repartitioning destroys the partition on your hard drive and creates several smaller partitions instead. Backup any needed data from the original partition as this method deletes the complete contents.

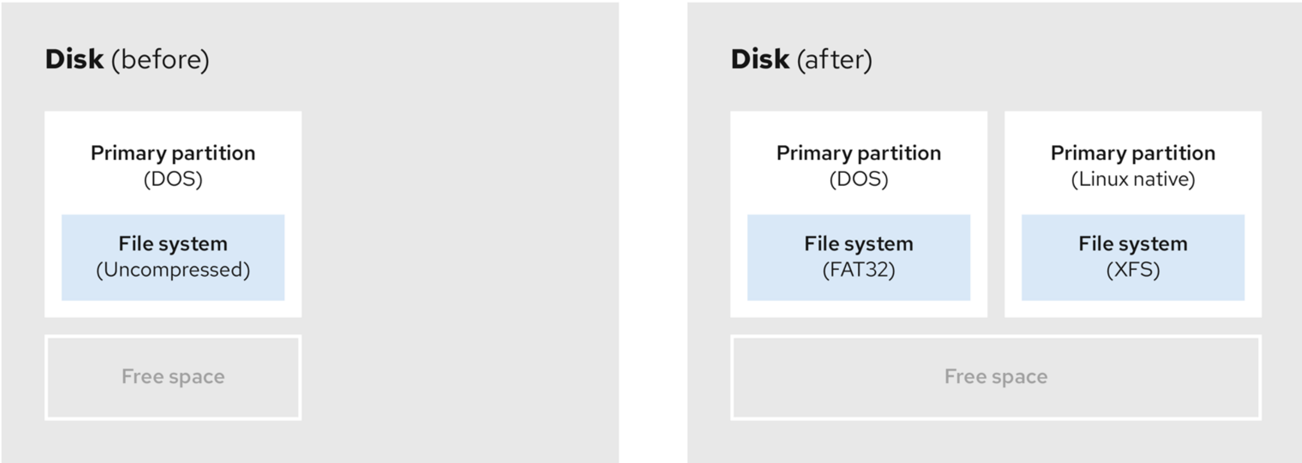
After creating a smaller partition for your existing operating system, you can:

- Reinstall software.
- Restore your data.

- Start your Red Hat Enterprise Linux installation.

The following diagram is a simplified representation of using the destructive repartitioning method.

Figure 8.3. Destructive repartitioning action on disk



> **WARNING**
>
> This method deletes all data previously stored in the original partition.

8.3.2. Non-destructive repartitioning

Non-destructive repartitioning resizes partitions, without any data loss. This method is reliable, however it takes longer processing time on large drives.

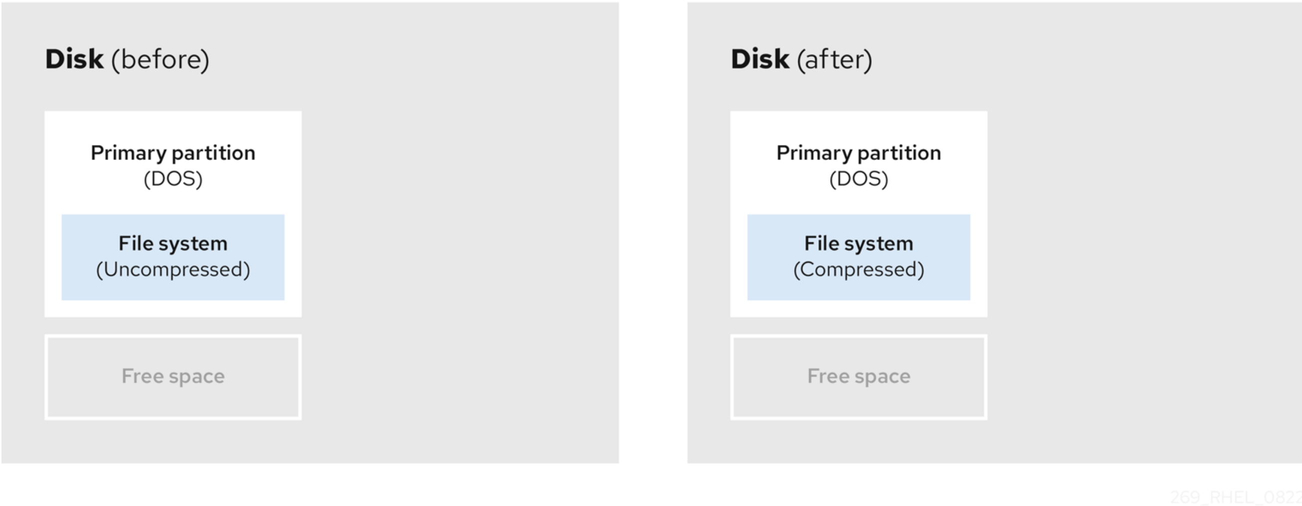
The following is a list of methods, which can help initiate non-destructive repartitioning.

- Compress existing data

The storage location of some data cannot be changed. This can prevent the resizing of a partition to the required size, and ultimately lead to a destructive repartition process. Compressing data in an already existing partition can help you resize your partitions as needed. It can also help to maximize the free space available.

The following diagram is a simplified representation of this process.

Figure 8.4. Data compression on a disk



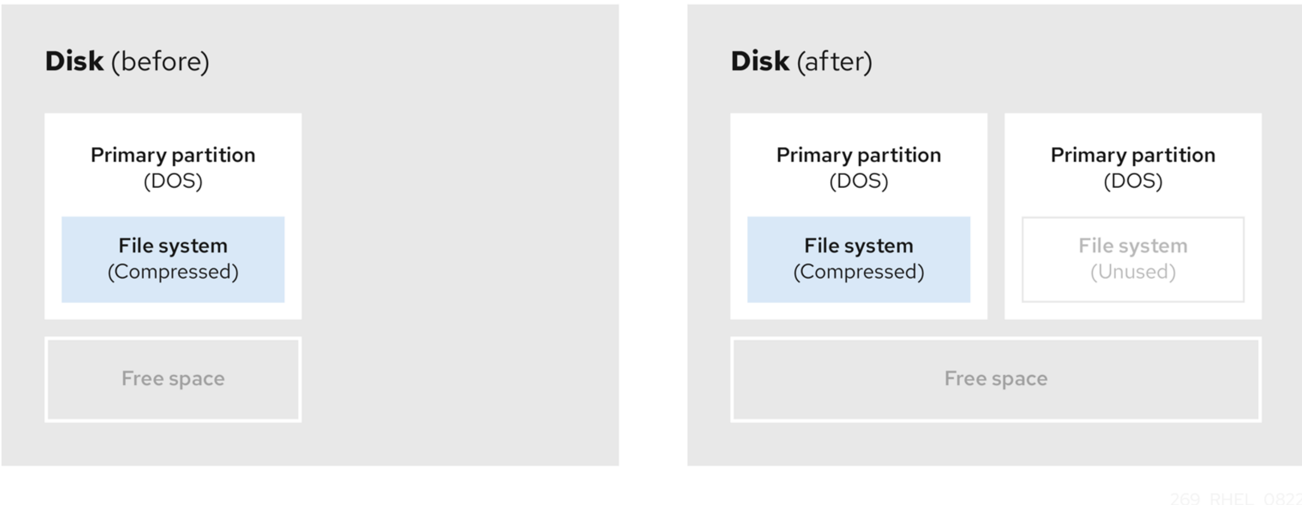
To avoid any possible data loss, create a backup before continuing with the compression process.

- Resize the existing partition

By resizing an already existing partition, you can free up more space. Depending on your resizing software, the results may vary. In the majority of cases, you can create a new unformatted partition of the same type, as the original partition.

The steps you take after resizing can depend on the software you use. In the following example, the best practice is to delete the new DOS (Disk Operating System) partition, and create a Linux partition instead. Verify what is most suitable for your disk before initiating the resizing process.

Figure 8.5. Partition resizing on a disk

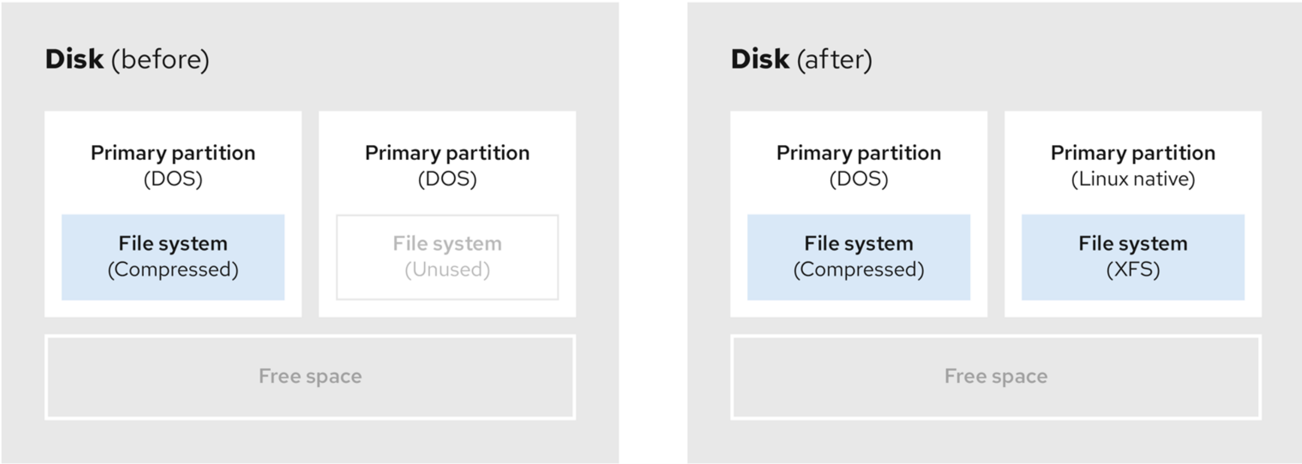


- Optional: Create new partitions

Some pieces of resizing software support Linux based systems. In such cases, there is no need to delete the newly created partition after resizing. Creating a new partition afterwards depends on the software you use.

The following diagram represents the disk state, before and after creating a new partition.

Figure 8.6. Disk with final partition configuration



CHAPTER 9. GETTING STARTED WITH XFS

This is an overview of how to create and maintain XFS file systems.

9.1. THE XFS FILE SYSTEM

XFS is a highly scalable, high-performance, robust, and mature 64-bit journaling file system that supports very large files and file systems on a single host. It is the default file system in Red Hat Enterprise Linux 9. XFS was originally developed in the early 1990s by SGI and has a long history of running on extremely large servers and storage arrays.

The features of XFS include:

Reliability

- Metadata journaling, which ensures file system integrity after a system crash by keeping a record of file system operations that can be replayed when the system is restarted and the file system remounted
- Extensive run-time metadata consistency checking
- Scalable and fast repair utilities
- Quota journaling. This avoids the need for lengthy quota consistency checks after a crash.

Scalability and performance

- Supported file system size up to 1024 TiB
- Ability to support a large number of concurrent operations
- B-tree indexing for scalability of free space management
- Sophisticated metadata read-ahead algorithms
- Optimizations for streaming video workloads

Allocation schemes

- Extent-based allocation
- Stripe-aware allocation policies
- Delayed allocation
- Space pre-allocation
- Dynamically allocated inodes

Other features

- Reflink-based file copies
- Tightly integrated backup and restore utilities
- Online defragmentation

- Online file system growing
- Comprehensive diagnostics capabilities
- Extended attributes (**xattr**). This allows the system to associate several additional name/value pairs per file.
- Project or directory quotas. This allows quota restrictions over a directory tree.
- Subsecond timestamps

Performance characteristics

XFS has a high performance on large systems with enterprise workloads. A large system is one with a relatively high number of CPUs, multiple HBAs, and connections to external disk arrays. XFS also performs well on smaller systems that have a multi-threaded, parallel I/O workload.

XFS has a relatively low performance for single threaded, metadata-intensive workloads: for example, a workload that creates or deletes large numbers of small files in a single thread.

9.2. COMPARISON OF TOOLS USED WITH EXT4 AND XFS

This section compares which tools to use to accomplish common tasks on the ext4 and XFS file systems.

Task	ext4	XFS
Create a file system	**mkfs.ext4**	**mkfs.xfs**
File system check	**e2fsck**	**xfs_repair**
Resize 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**
Back up a file system	**tar** and **rsync**	**xfsdump** and **xfsrestore**
Quota management	**quota**	**xfs_quota**
File mapping	**filefrag**	**xfs_bmap**

NOTE

If you want a complete client-server solution for backups over network, you can use **bacula** backup utility that is available in RHEL 9. For more information about Bacula, see Bacula backup solution.

CHAPTER 10. CREATING AN XFS FILE SYSTEM

As a system administrator, you can create an XFS file system on a block device to enable it to store files and directories.

10.1. CREATING AN XFS FILE SYSTEM WITH MKFS.XFS

This procedure describes how to create an XFS file system on a block device.

Procedure

1. To create the file system:
   - If the device is a regular partition, an LVM volume, an MD volume, a disk, or a similar device, use the following command:

     ```
     # mkfs.xfs block-device
     ```

     - Replace *block-device* with the path to the block device. For example, **/dev/sdb1**, **/dev/disk/by-uuid/05e99ec8-def1-4a5e-8a9d-5945339ceb2a**, or **/dev/my-volgroup/my-lv**.
     - In general, the default options are optimal for common use.
     - When using **mkfs.xfs** on a block device containing an existing file system, add the **-f** option to overwrite that file system.
   - To create the file system on a hardware RAID device, check if the system correctly detects the stripe geometry of the device:
     - If the stripe geometry information is correct, no additional options are needed. Create the file system:

       ```
       # mkfs.xfs block-device
       ```

     - If the information is incorrect, specify stripe geometry manually with the **su** and **sw** parameters of the **-d** option. The **su** parameter specifies the RAID chunk size, and the **sw** parameter specifies the number of data disks in the RAID device.
       For example:

       ```
       # mkfs.xfs -d su=64k,sw=4 /dev/sda3
       ```

2. Use the following command to wait for the system to register the new device node:

   ```
   # udevadm settle
   ```

Additional resources

- **mkfs.xfs(8)** man page on your system

CHAPTER 11. BACKING UP AN XFS FILE SYSTEM

As a system administrator, you can use the **xfsdump** to back up an XFS file system into a file or on a tape. This provides a simple backup mechanism.

11.1. FEATURES OF XFS BACKUP

This section describes key concepts and features of backing up an XFS file system with the **xfsdump** utility.

You can use the **xfsdump** utility to:

- Perform backups to regular file images.
  Only one backup can be written to a regular file.

- Perform backups to tape drives.
  The **xfsdump** utility also enables you to write multiple backups to the same tape. A backup can span multiple tapes.

  To back up multiple file systems to a single tape device, simply write the backup to a tape that already contains an XFS backup. This appends the new backup to the previous one. By default, **xfsdump** never overwrites existing backups.

- Create incremental backups.
  The **xfsdump** utility uses dump levels to determine a base backup to which other backups are relative. Numbers from 0 to 9 refer to increasing dump levels. An incremental backup only backs up files that have changed since the last dump of a lower level:

  - To perform a full backup, perform a level 0 dump on the file system.

  - A level 1 dump is the first incremental backup after a full backup. The next incremental backup would be level 2, which only backs up files that have changed since the last level 1 dump; and so on, to a maximum of level 9.

- Exclude files from a backup using size, subtree, or inode flags to filter them.

Additional resources

- **xfsdump(8)** man page on your system

11.2. BACKING UP AN XFS FILE SYSTEM WITH XFSDUMP

This procedure describes how to back up the content of an XFS file system into a file or a tape.

Prerequisites

- An XFS file system that you can back up.

- Another file system or a tape drive where you can store the backup.

Procedure

- Use the following command to back up an XFS file system:

```
# xfsdump -l level [-L label] \ -f backup-destination path-to-xfs-filesystem
```

- Replace *level* with the dump level of your backup. Use **0** to perform a full backup or **1** to **9** to perform consequent incremental backups.
- Replace *backup-destination* with the path where you want to store your backup. The destination can be a regular file, a tape drive, or a remote tape device. For example, **/backup-files/Data.xfsdump** for a file or **/dev/st0** for a tape drive.
- Replace *path-to-xfs-filesystem* with the mount point of the XFS file system you want to back up. For example, **/mnt/data/**. The file system must be mounted.
- When backing up multiple file systems and saving them on a single tape device, add a session label to each backup using the **-L *label*** option so that it is easier to identify them when restoring. Replace *label* with any name for your backup: for example, **backup_data**.

Example 11.1. Backing up multiple XFS file systems

- To back up the content of XFS file systems mounted on the **/boot/** and **/data/** directories and save them as files in the **/backup-files/** directory:

```
# xfsdump -l 0 -f /backup-files/boot.xfsdump /boot
# xfsdump -l 0 -f /backup-files/data.xfsdump /data
```

- To back up multiple file systems on a single tape device, add a session label to each backup using the **-L *label*** option:

```
# xfsdump -l 0 -L "backup_boot" -f /dev/st0 /boot
# xfsdump -l 0 -L "backup_data" -f /dev/st0 /data
```

Additional resources

- **xfsdump(8)** man page on your system

CHAPTER 12. RESTORING AN XFS FILE SYSTEM FROM BACKUP

As a system administrator, you can use the **xfsrestore** utility to restore XFS backup created with the **xfsdump** utility and stored in a file or on a tape.

12.1. FEATURES OF RESTORING XFS FROM BACKUP

The **xfsrestore** utility restores file systems from backups produced by **xfsdump**. The **xfsrestore** utility has two modes:

- The **simple** mode enables users to restore an entire file system from a level 0 dump. This is the default mode.
- The **cumulative** mode enables file system restoration from an incremental backup: that is, level 1 to level 9.

A unique *session ID* or *session label* identifies each backup. Restoring a backup from a tape containing multiple backups requires its corresponding session ID or label.

To extract, add, or delete specific files from a backup, enter the **xfsrestore** interactive mode. The interactive mode provides a set of commands to manipulate the backup files.

Additional resources

- **xfsrestore(8)** man page on your system

12.2. RESTORING AN XFS FILE SYSTEM FROM BACKUP WITH XFSRESTORE

This procedure describes how to restore the content of an XFS file system from a file or tape backup.

Prerequisites

- A file or tape backup of XFS file systems, as described in Backing up an XFS file system .
- A storage device where you can restore the backup.

Procedure

- The command to restore the backup varies depending on whether you are restoring from a full backup or an incremental one, or are restoring multiple backups from a single tape device:

  ```
  # xfsrestore [-r] [-S session-id] [-L session-label] [-i] -f backup-location restoration-path
  ```

  - Replace *backup-location* with the location of the backup. This can be a regular file, a tape drive, or a remote tape device. For example, **/backup-files/Data.xfsdump** for a file or **/dev/st0** for a tape drive.
  - Replace *restoration-path* with the path to the directory where you want to restore the file system. For example, **/mnt/data/**.
  - To restore a file system from an incremental (level 1 to level 9) backup, add the **-r** option.

- To restore a backup from a tape device that contains multiple backups, specify the backup using the **-S** or **-L** options.
  The **-S** option lets you choose a backup by its session ID, while the **-L** option lets you choose by the session label. To obtain the session ID and session labels, use the **xfsrestore -I** command.

  Replace *session-id* with the session ID of the backup. For example, **b74a3586-e52e-4a4a-8775-c3334fa8ea2c**. Replace *session-label* with the session label of the backup. For example, **my_backup_session_label**.

- To use **xfsrestore** interactively, use the **-i** option.
  The interactive dialog begins after **xfsrestore** finishes reading the specified device. Available commands in the interactive **xfsrestore** shell include **cd**, **ls**, **add**, **delete**, and **extract**; for a complete list of commands, use the **help** command.

Example 12.1. Restoring Multiple XFS File Systems

- To restore the XFS backup files and save their content into directories under **/mnt/**:

```
# xfsrestore -f /backup-files/boot.xfsdump /mnt/boot/
# xfsrestore -f /backup-files/data.xfsdump /mnt/data/
```

- To restore from a tape device containing multiple backups, specify each backup by its session label or session ID:

```
# xfsrestore -L "backup_boot" -f /dev/st0 /mnt/boot/
# xfsrestore -S "45e9af35-efd2-4244-87bc-4762e476cbab" \ -f /dev/st0 /mnt/data/
```

Additional resources

- **xfsrestore(8)** man page on your system

12.3. INFORMATIONAL MESSAGES WHEN RESTORING AN XFS BACKUP FROM A TAPE

When restoring a backup from a tape with backups from multiple file systems, the **xfsrestore** utility might issue messages. The messages inform you whether a match of the requested backup has been found when **xfsrestore** examines each backup on the tape in sequential order. For example:

```
xfsrestore: preparing drive
xfsrestore: examining media file 0
xfsrestore: inventory session uuid (8590224e-3c93-469c-a311-fc8f23029b2a) does not match the
media header's session uuid (7eda9f86-f1e9-4dfd-b1d4-c50467912408)
xfsrestore: examining media file 1
xfsrestore: inventory session uuid (8590224e-3c93-469c-a311-fc8f23029b2a) does not match the
media header's session uuid (7eda9f86-f1e9-4dfd-b1d4-c50467912408)
[...]
```

The informational messages keep appearing until the matching backup is found.

CHAPTER 13. INCREASING THE SIZE OF AN XFS FILE SYSTEM

As a system administrator, you can increase the size of an XFS file system to make a complete use of a larger storage capacity.

> **IMPORTANT**
>
> It is not currently possible to decrease the size of XFS file systems.

13.1. INCREASING THE SIZE OF AN XFS FILE SYSTEM WITH XFS_GROWFS

This procedure describes how to grow an XFS file system using the **xfs_growfs** utility.

Prerequisites

- Ensure that the underlying block device is of an appropriate size to hold the resized file system later. Use the appropriate resizing methods for the affected block device.
- Mount the XFS file system.

Procedure

- While the XFS file system is mounted, use the **xfs_growfs** utility to increase its size:

  ```
  # xfs_growfs file-system -D new-size
  ```

  - Replace *file-system* with the mount point of the XFS file system.
  - With the **-D** option, replace *new-size* with the desired new size of the file system specified in the number of file system blocks.
    To find out the block size in kB of a given XFS file system, use the **xfs_info** utility:

    ```
    # xfs_info block-device

    ...
    data     =              bsize=4096
    ...
    ```

  - Without the **-D** option, **xfs_growfs** grows the file system to the maximum size supported by the underlying device.

Additional resources

- **xfs_growfs(8)** man page on your system.

CHAPTER 14. CONFIGURING XFS ERROR BEHAVIOR

You can configure how an XFS file system behaves when it encounters different I/O errors.

14.1. CONFIGURABLE ERROR HANDLING IN XFS

The XFS file system responds in one of the following ways when an error occurs during an I/O operation:

- XFS repeatedly retries the I/O operation until the operation succeeds or XFS reaches a set limit. The limit is based either on a maximum number of retries or a maximum time for retries.
- XFS considers the error permanent and stops the operation on the file system.

You can configure how XFS reacts to the following error conditions:

EIO

Error when reading or writing

ENOSPC

No space left on the device

ENODEV

Device cannot be found

You can set the maximum number of retries and the maximum time in seconds until XFS considers an error permanent. XFS stops retrying the operation when it reaches either of the limits.

You can also configure XFS so that when unmounting a file system, XFS immediately cancels the retries regardless of any other configuration. This configuration enables the unmount operation to succeed despite persistent errors.

Default behavior

The default behavior for each XFS error condition depends on the error context. Some XFS errors such as **ENODEV** are considered to be fatal and unrecoverable, regardless of the retry count. Their default retry limit is 0.

14.2. CONFIGURATION FILES FOR SPECIFIC AND UNDEFINED XFS ERROR CONDITIONS

The following directories store configuration files that control XFS error behavior for different error conditions:

/sys/fs/xfs/*device*/error/metadata/EIO/

For the **EIO** error condition

/sys/fs/xfs/*device*/error/metadata/ENODEV/

For the **ENODEV** error condition

/sys/fs/xfs/*device*/error/metadata/ENOSPC/

For the **ENOSPC** error condition

/sys/fs/xfs/*device*/error/default/

Common configuration for all other, undefined error conditions

Each directory contains the following configuration files for configuring retry limits:

max_retries

Controls the maximum number of times that XFS retries the operation.

retry_timeout_seconds

Specifies the time limit in seconds after which XFS stops retrying the operation.

14.3. SETTING XFS BEHAVIOR FOR SPECIFIC CONDITIONS

This procedure configures how XFS reacts to specific error conditions.

Procedure

- Set the maximum number of retries, the retry time limit, or both:
  - To set the maximum number of retries, write the desired number to the **max_retries** file:

    ```
    # echo value > /sys/fs/xfs/device/error/metadata/condition/max_retries
    ```

  - To set the time limit, write the desired number of seconds to the **retry_timeout_seconds** file:

    ```
    # echo value > /sys/fs/xfs/device/error/metadata/condition/retry_timeout_second
    ```

  value is a number between -1 and the maximum possible value of the C signed integer type. This is 2147483647 on 64-bit Linux.

  In both limits, the value **-1** is used for continuous retries and **0** to stop immediately.

  device is the name of the device, as found in the **/dev/** directory; for example, **sda**.

14.4. SETTING XFS BEHAVIOR FOR UNDEFINED CONDITIONS

This procedure configures how XFS reacts to all undefined error conditions, which share a common configuration.

Procedure

- Set the maximum number of retries, the retry time limit, or both:
  - To set the maximum number of retries, write the desired number to the **max_retries** file:

    ```
    # echo value > /sys/fs/xfs/device/error/metadata/default/max_retries
    ```

  - To set the time limit, write the desired number of seconds to the **retry_timeout_seconds** file:

    ```
    # echo value > /sys/fs/xfs/device/error/metadata/default/retry_timeout_seconds
    ```

  value is a number between -1 and the maximum possible value of the C signed integer type. This is 2147483647 on 64-bit Linux.

In both limits, the value **-1** is used for continuous retries and **0** to stop immediately.

device is the name of the device, as found in the **/dev/** directory; for example, **sda**.

14.5. SETTING THE XFS UNMOUNT BEHAVIOR

This procedure configures how XFS reacts to error conditions when unmounting the file system.

If you set the **fail_at_unmount** option in the file system, it overrides all other error configurations during unmount, and immediately unmounts the file system without retrying the I/O operation. This allows the unmount operation to succeed even in case of persistent errors.

> **WARNING**
>
> You cannot change the **fail_at_unmount** value after the unmount process starts, because the unmount process removes the configuration files from the **sysfs** interface for the respective file system. You must configure the unmount behavior before the file system starts unmounting.

Procedure

- Enable or disable the **fail_at_unmount** option:
  - To cancel retrying all operations when the file system unmounts, enable the option:

    ```
    # echo 1 > /sys/fs/xfs/device/error/fail_at_unmount
    ```

  - To respect the **max_retries** and **retry_timeout_seconds** retry limits when the file system unmounts, disable the option:

    ```
    # echo 0 > /sys/fs/xfs/device/error/fail_at_unmount
    ```

device is the name of the device, as found in the **/dev/** directory; for example, **sda**.

CHAPTER 15. CHECKING AND REPAIRING A FILE SYSTEM

RHEL provides file system administration utilities which are capable of checking and repairing file systems. These tools are often referred to as **fsck** tools, where **fsck** is a shortened version of *file system check*. In most cases, these utilities are run automatically during system boot, if needed, but can also be manually invoked if required.

> **IMPORTANT**
>
> File system checkers guarantee only metadata consistency across the file system. They have no awareness of the actual data contained within the file system and are not data recovery tools.

15.1. SCENARIOS THAT REQUIRE A FILE SYSTEM CHECK

The relevant **fsck** tools can be used to check your system if any of the following occurs:

- System fails to boot
- Files on a specific disk become corrupt
- The file system shuts down or changes to read-only due to inconsistencies
- A file on the file system is inaccessible

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

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

For journaling file systems, all that is normally required at boot time is to replay the journal if required and this is usually a very short operation.

However, if a file system inconsistency or corruption occurs, even for journaling file systems, then the file system checker must be used to repair the file system.

> **IMPORTANT**
>
> It is possible to disable file system check at boot by setting the sixth field in **/etc/fstab** to **0**. However, Red Hat does not recommend doing so unless you are having issues with **fsck** at boot time, for example with extremely large or remote file systems.

Additional resources

- **fstab(5)**, **fsck(8)**, and **dd(8)** man pages on your system

15.2. POTENTIAL SIDE EFFECTS OF RUNNING FSCK

Generally, running the file system check and repair tool can be expected to automatically repair at least some of the inconsistencies it finds. In some cases, the following issues can arise:

- Severely damaged inodes or directories may be discarded if they cannot be repaired.
- Significant changes to the file system may occur.

To ensure that unexpected or undesirable changes are not permanently made, ensure you follow any precautionary steps outlined in the procedure.

15.3. ERROR-HANDLING MECHANISMS IN XFS

This section describes how XFS handles various kinds of errors in the file system.

Unclean unmounts

Journalling maintains a transactional record of metadata changes that happen on the file system.

In the event of a system crash, power failure, or other unclean unmount, XFS uses the journal (also called log) to recover the file system. The kernel performs journal recovery when mounting the XFS file system.

Corruption

In this context, *corruption* means errors on the file system caused by, for example:

- Hardware faults
- Bugs in storage firmware, device drivers, the software stack, or the file system itself
- Problems that cause parts of the file system to be overwritten by something outside of the file system

When XFS detects corruption in the file system or the file-system metadata, it may shut down the file system and report the incident in the system log. Note that if the corruption occurred on the file system hosting the **/var** directory, these logs will not be available after a reboot.

Example 15.1. System log entry reporting an XFS corruption

```
# dmesg --notime | tail -15

XFS (loop0): Mounting V5 Filesystem
XFS (loop0): Metadata CRC error detected at xfs_agi_read_verify+0xcb/0xf0 [xfs], xfs_agi block
0x2
XFS (loop0): Unmount and run xfs_repair
XFS (loop0): First 128 bytes of corrupted metadata buffer:
00000000027b3b56: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000000005f9abc7a: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000000005b0aef35: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000000da9d2ded: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000000001e265b07: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000000006a40df69: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000000000b272907: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000000e484aac5: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
XFS (loop0): metadata I/O error in "xfs_trans_read_buf_map" at daddr 0x2 len 1 error 74
XFS (loop0): xfs_imap_lookup: xfs_ialloc_read_agi() returned error -117, agno 0
XFS (loop0): Failed to read root inode 0x80, error 11
```

User-space utilities usually report the *Input/output error* message when trying to access a corrupted XFS file system. Mounting an XFS file system with a corrupted log results in a failed mount and the following error message:

```
mount: /mount-point: mount(2) system call failed: Structure needs cleaning.
```

You must manually use the **xfs_repair** utility to repair the corruption.

Additional resources

- **xfs_repair(8)** man page on your system

15.4. CHECKING AN XFS FILE SYSTEM WITH XFS_REPAIR

Perform a read-only check of an XFS file system by using the xfs_repair utility. Unlike other file system repair utilities, **xfs_repair** does not run at boot time, even when an XFS file system was not cleanly unmounted. In case of an unclean unmount, XFS simply replays the log at mount time, ensuring a consistent file system; **xfs_repair** cannot repair an XFS file system with a dirty log without remounting it first.

> **NOTE**
>
> Although an **fsck.xfs** binary is present in the **xfsprogs** package, this is present only to satisfy **initscripts** that look for an **fsck.file** system binary at boot time. **fsck.xfs** immediately exits with an exit code of 0.

Procedure

1. Replay the log by mounting and unmounting the file system:

   ```
   # mount file-system
   # umount file-system
   ```

   > **NOTE**
   >
   > If the mount fails with a structure needs cleaning error, the log is corrupted and cannot be replayed. The dry run should discover and report more on-disk corruption as a result.

2. Use the **xfs_repair** utility to perform a dry run to check the file system. Any errors are printed and an indication of the actions that would be taken, without modifying the file system.

   ```
   # xfs_repair -n block-device
   ```

3. Mount the file system:

   ```
   # mount file-system
   ```

Additional resources

- **xfs_repair(8)** and **xfs_metadump(8)** man pages on your system

15.5. REPAIRING AN XFS FILE SYSTEM WITH XFS_REPAIR

This procedure repairs a corrupted XFS file system using the **xfs_repair** utility.

Procedure

1. Create a metadata image prior to repair for diagnostic or testing purposes using the **xfs_metadump** utility. A pre-repair file system metadata image can be useful for support investigations if the corruption is due to a software bug. Patterns of corruption present in the pre-repair image can aid in root-cause analysis.

   - Use the **xfs_metadump** debugging tool to copy the metadata from an XFS file system to a file. The resulting **metadump** file can be compressed using standard compression utilities to reduce the file size if large **metadump** files need to be sent to support.

     ```
     # xfs_metadump block-device metadump-file
     ```

2. Replay the log by remounting the file system:

   ```
   # mount file-system
   # umount file-system
   ```

3. Use the **xfs_repair** utility to repair the unmounted file system:

   - If the mount succeeded, no additional options are required:

     ```
     # xfs_repair block-device
     ```

   - If the mount failed with the *Structure needs cleaning* error, the log is corrupted and cannot be replayed. Use the **-L** option (*force log zeroing*) to clear the log:

     > **WARNING**
     >
     > This command causes all metadata updates in progress at the time of the crash to be lost, which might cause significant file system damage and data loss. This should be used only as a last resort if the log cannot be replayed.

     ```
     # xfs_repair -L block-device
     ```

4. Mount the file system:

   ```
   # mount file-system
   ```

Additional resources

- **xfs_repair(8)** man page on your system

15.6. ERROR HANDLING MECHANISMS IN EXT2, EXT3, AND EXT4

The ext2, ext3, and ext4 file systems use the **e2fsck** utility to perform file system checks and repairs. The file names **fsck.ext2**, **fsck.ext3**, and **fsck.ext4** are hardlinks to the **e2fsck** utility. These binaries are run automatically at boot time and their behavior differs based on the file system being checked and the state of the file system.

A full file system check and repair is invoked for ext2, which is not a metadata journaling file system, and for ext4 file systems without a journal.

For ext3 and ext4 file systems with metadata journaling, the journal is replayed in userspace and the utility exits. This is the default action because journal replay ensures a consistent file system after a crash.

If these file systems encounter metadata inconsistencies while mounted, they record this fact in the file system superblock. If **e2fsck** finds that a file system is marked with such an error, **e2fsck** performs a full check after replaying the journal (if present).

Additional resources

- **fsck(8)** and **e2fsck(8)** man pages on your system

15.7. CHECKING AN EXT2, EXT3, OR EXT4 FILE SYSTEM WITH E2FSCK

This procedure checks an ext2, ext3, or ext4 file system using the **e2fsck** utility.

Procedure

1. Replay the log by remounting the file system:

```
# mount file-system
# umount file-system
```

2. Perform a dry run to check the file system.

```
# e2fsck -n block-device
```

NOTE

Any errors are printed and an indication of the actions that would be taken, without modifying the file system. 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.

Additional resources

- **e2image(8)** and **e2fsck(8)** man pages on your system

15.8. REPAIRING AN EXT2, EXT3, OR EXT4 FILE SYSTEM WITH E2FSCK

This procedure repairs a corrupted ext2, ext3, or ext4 file system using the **e2fsck** utility.

Procedure

1. Save a file system image for support investigations. A pre-repair file system metadata image can be useful for support investigations if the corruption is due to a software bug. Patterns of corruption present in the pre-repair image can aid in root-cause analysis.

   > **NOTE**
   >
   > Severely damaged file systems may cause problems with metadata image creation.

   - If you are creating the image for testing purposes, use the **-r** option to create a sparse file of the same size as the file system itself. **e2fsck** can then operate directly on the resulting file.

     ```
     # e2image -r block-device image-file
     ```

   - If you are creating the image to be archived or provided for diagnostic, use the **-Q** option, which creates a more compact file format suitable for transfer.

     ```
     # e2image -Q block-device image-file
     ```

2. Replay the log by remounting the file system:

   ```
   # mount file-system
   # umount file-system
   ```

3. Automatically repair the file system. If user intervention is required, **e2fsck** indicates the unfixed problem in its output and reflects this status in the exit code.

   ```
   # e2fsck -p block-device
   ```

Additional resources

- **e2image(8)** man page on your system
- **e2fsck(8)** man page on your system

CHAPTER 16. MOUNTING FILE SYSTEMS

As a system administrator, you can mount file systems on your system to access data on them.

16.1. THE LINUX MOUNT MECHANISM

These are the basic concepts of mounting file systems on Linux.

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. While a file system is mounted on a directory, the original content of the directory is not accessible.

Note that Linux does not prevent you from mounting a file system to a directory with a file system already attached to it.

When mounting, you can identify the device by:

- a universally unique identifier (UUID): for example, **UUID=34795a28-ca6d-4fd8-a347-73671d0c19cb**
- a volume label: for example, **LABEL=home**
- a full path to a non-persistent block device: for example, **/dev/sda3**

When you mount a file system using the **mount** command without all required information, that is without the device name, the target directory, or the file system type, the **mount** utility reads the content of the **/etc/fstab** file to check if the given file system is listed there. The **/etc/fstab** file contains a list of device names and the directories in which the selected file systems are set to be mounted as well as the file system type and mount options. Therefore, when mounting a file system that is specified in **/etc/fstab**, the following command syntax is sufficient:

- Mounting by the mount point:

```
# mount directory
```

- Mounting by the block device:

```
# mount device
```

Additional resources

- **mount(8)** man page on your system
- How to list persistent naming attributes such as the UUID .

16.2. LISTING CURRENTLY MOUNTED FILE SYSTEMS

List all currently mounted file systems on the command line by using the **findmnt** utility.

Procedure

- To list all mounted file systems, use the **findmnt** utility:

```
$ findmnt
```

- To limit the listed file systems only to a certain file system type, add the **--types** option:

```
$ findmnt --types fs-type
```

For example:

Example 16.1. Listing only XFS file systems

```
$ findmnt --types xfs

TARGET  SOURCE                                              FSTYPE OPTIONS
/       /dev/mapper/luks-5564ed00-6aac-4406-bfb4-c59bf5de48b5 xfs    rw,relatime
├─/boot /dev/sda1                                          xfs    rw,relatime
└─/home /dev/mapper/luks-9d185660-7537-414d-b727-d92ea036051e xfs    rw,relatime
```

Additional resources

- **findmnt(8)** man page on your system

16.3. MOUNTING A FILE SYSTEM WITH MOUNT

Mount a file system by using the **mount** utility.

Prerequisites

- Verify that no file system is already mounted on your chosen mount point:

```
$ findmnt mount-point
```

Procedure

1. To attach a certain file system, use the **mount** utility:

```
# mount device mount-point
```

Example 16.2. Mounting an XFS file system

For example, to mount a local XFS file system identified by UUID:

```
# mount UUID=ea74bbec-536d-490c-b8d9-5b40bbd7545b /mnt/data
```

2. If **mount** cannot recognize the file system type automatically, specify it using the **--types** option:

```
# mount --types type device mount-point
```

Example 16.3. Mounting an NFS file system

For example, to mount a remote NFS file system:

```
# mount --types nfs4 host:/remote-export /mnt/nfs
```

Additional resources

- **mount(8)** man page on your system

16.4. MOVING A MOUNT POINT

Change the mount point of a mounted file system to a different directory by using the **mount** utility.

Procedure

1. To change the directory in which a file system is mounted:

```
# mount --move old-directory new-directory
```

Example 16.4. Moving a home file system

For example, to move the file system mounted in the **/mnt/userdirs/** directory to the **/home/** mount point:

```
# mount --move /mnt/userdirs /home
```

2. Verify that the file system has been moved as expected:

```
$ findmnt
$ ls old-directory
$ ls new-directory
```

Additional resources

- **mount(8)** man page on your system

16.5. UNMOUNTING A FILE SYSTEM WITH UMOUNT

Unmount a file system by using the **umount** utility.

Procedure

1. Try unmounting the file system using either of the following commands:
   - By mount point:

```
# umount mount-point
```

- By device:

```
# umount device
```

If the command fails with an error similar to the following, it means that the file system is in use because of a process is using resources on it:

```
umount: /run/media/user/FlashDrive: target is busy.
```

2. If the file system is in use, use the **fuser** utility to determine which processes are accessing it.
For example:

```
$ fuser --mount /run/media/user/FlashDrive /run/media/user/FlashDrive: 18351
```

Afterwards, stop the processes using the file system and try unmounting it again.

16.6. MOUNTING AND UNMOUNTING FILE SYSTEMS IN THE WEB CONSOLE

To be able to use partitions on RHEL systems, you need to mount a file system on the partition as a device.

> **NOTE**
>
> You also can unmount a file system and the RHEL system will stop using it. Unmounting the file system enables you to delete, remove, or re-format devices.

Prerequisites

- The **cockpit-storaged** package is installed on your system.
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see Installing and enabling the web console .
- If you want to unmount a file system, ensure that the system does not use any file, service, or application stored in the partition.

Procedure

1. Log in to the RHEL 9 web console.
For details, see Logging in to the web console .
2. Click the **Storage** tab.
3. In the **Storage** table, select a volume from which you want to delete the partition.
4. In the **GPT partitions** section, click the menu button, ⋮ next to the partition whose file system you want to mount or unmount.

5. Click **Mount** or **Unmount**.

16.7. COMMON MOUNT OPTIONS

The following table lists the most common options of the **mount** utility. You can apply these mount options using the following syntax:

```
# mount --options option1,option2,option3 device mount-point
```

Table 16.1. Common mount options

Option	Description
async	Enables asynchronous input and output operations on the file system.
auto	Enables the file system to be mounted automatically using the **mount -a** command.
defaults	Provides an alias for the **async,auto,dev,exec,nouser,rw,suid** options.
exec	Allows the execution of binary files on the particular file system.
loop	Mounts an image as a loop device.
noauto	Default behavior disables 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.

CHAPTER 17. SHARING A MOUNT ON MULTIPLE MOUNT POINTS

As a system administrator, you can duplicate mount points to make the file systems accessible from multiple directories.

17.1. TYPES OF SHARED MOUNTS

There are multiple types of shared mounts that you can use. The difference between them is what happens when you mount another file system under one of the shared mount points. The shared mounts are implemented using the *shared subtrees* functionality.

The following mount types are available:

private

This type does not receive or forward any propagation events.
When you mount another file system under either the duplicate or the original mount point, it is not reflected in the other.

shared

This type creates 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.

This is the default mount type of the root file system.

slave

This type creates 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.

unbindable

This type prevents the given mount point from being duplicated whatsoever.

Additional resources

- The *Shared subtrees* article on Linux Weekly News

17.2. CREATING A PRIVATE MOUNT POINT DUPLICATE

Duplicate a mount point as a private mount. File systems that you later mount under the duplicate or the original mount point are not reflected in the other.

Procedure

1. Create a virtual file system (VFS) node from the original mount point:

```
# mount --bind original-dir original-dir
```

2. Mark the original mount point as private:

```
# mount --make-private original-dir
```

Alternatively, to change the mount type for the selected mount point and all mount points under it, use the **--make-rprivate** option instead of **--make-private**.

3. Create the duplicate:

```
# mount --bind original-dir duplicate-dir
```

Example 17.1. Duplicating /media into /mnt as a private mount point

1. Create a VFS node from the **/media** directory:

```
# mount --bind /media /media
```

2. Mark the **/media** directory as private:

```
# mount --make-private /media
```

3. Create its duplicate in **/mnt**:

```
# mount --bind /media /mnt
```

4. It is now possible to verify that **/media** and **/mnt** share content but none of the mounts within **/media** appear in **/mnt**. For example, if the CD-ROM drive contains non-empty media and the **/media/cdrom/** directory exists, use:

```
# mount /dev/cdrom /media/cdrom
# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
# ls /mnt/cdrom
#
```

5. It is also possible to verify that file systems mounted in the **/mnt** directory are not reflected in **/media**. For example, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, use:

```
# mount /dev/sdc1 /mnt/flashdisk
# ls /media/flashdisk
# ls /mnt/flashdisk
en-US  publican.cfg
```

Additional resources

- **mount(8)** man page on your system

17.3. CREATING A SHARED MOUNT POINT DUPLICATE

Duplicate a mount point as a shared mount. File systems that you later mount under the original directory or the duplicate are always reflected in the other.

Procedure

1. Create a virtual file system (VFS) node from the original mount point:

```
# mount --bind original-dir original-dir
```

2. Mark the original mount point as shared:

```
# mount --make-shared original-dir
```

Alternatively, to change the mount type for the selected mount point and all mount points under it, use the **--make-rshared** option instead of **--make-shared**.

3. Create the duplicate:

```
# mount --bind original-dir duplicate-dir
```

Example 17.2. Duplicating /media into /mnt as a shared mount point

To make the **/media** and **/mnt** directories share the same content:

1. Create a VFS node from the **/media** directory:

```
# mount --bind /media /media
```

2. Mark the **/media** directory as shared:

```
# mount --make-shared /media
```

3. Create its duplicate in **/mnt**:

```
# mount --bind /media /mnt
```

4. 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, use:

```
# mount /dev/cdrom /media/cdrom
# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
# ls /mnt/cdrom
EFI  GPL  isolinux  LiveOS
```

5. Similarly, it is possible to verify that any file system mounted in the **/mnt** directory is reflected in **/media**. For example, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, use:

```
# mount /dev/sdc1 /mnt/flashdisk
# ls /media/flashdisk
en-US  publican.cfg
# ls /mnt/flashdisk
en-US  publican.cfg
```

Additional resources

- **mount(8)** man page on your system

17.4. CREATING A SLAVE MOUNT POINT DUPLICATE

Duplicate a mount point as a **slave** mount type. File systems that you later mount under the original mount point are reflected in the duplicate but not the other way around.

Procedure

1. Create a virtual file system (VFS) node from the original mount point:

```
# mount --bind original-dir original-dir
```

2. Mark the original mount point as shared:

```
# mount --make-shared original-dir
```

   Alternatively, to change the mount type for the selected mount point and all mount points under it, use the **--make-rshared** option instead of **--make-shared**.

3. Create the duplicate and mark it as the **slave** type:

```
# mount --bind original-dir duplicate-dir
# mount --make-slave duplicate-dir
```

Example 17.3. Duplicating /media into /mnt as 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**.

1. Create a VFS node from the /**media** directory:

```
# mount --bind /media /media
```

2. Mark the /**media** directory as shared:

```
# mount --make-shared /media
```

3. Create its duplicate in /**mnt** and mark it as **slave**:

```
# mount --bind /media /mnt
# mount --make-slave /mnt
```

4. 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, use:

```
# mount /dev/cdrom /media/cdrom
# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
```

```
# ls /mnt/cdrom
EFI  GPL  isolinux  LiveOS
```

5. Also verify that file systems mounted in the **/mnt** directory are not reflected in **/media**. For example, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, use:

```
# mount /dev/sdc1 /mnt/flashdisk
# ls /media/flashdisk
# ls /mnt/flashdisk
en-US  publican.cfg
```

Additional resources

- **mount(8)** man page on your system

17.5. PREVENTING A MOUNT POINT FROM BEING DUPLICATED

Mark a mount point as unbindable so that it is not possible to duplicate it in another mount point.

Procedure

- To change the type of a mount point to an unbindable mount, use:

```
# mount --bind mount-point mount-point
# mount --make-unbindable mount-point
```

  Alternatively, to change the mount type for the selected mount point and all mount points under it, use the **--make-runbindable** option instead of **--make-unbindable**.

  Any subsequent attempt to make a duplicate of this mount fails with the following error:

```
# mount --bind mount-point duplicate-dir

mount: wrong fs type, bad option, bad superblock on mount-point,
missing codepage or helper program, or other error
In some cases useful info is found in syslog - try
dmesg | tail  or so
```

Example 17.4. Preventing /media from being duplicated

- To prevent the **/media** directory from being shared, use:

```
# mount --bind /media /media
# mount --make-unbindable /media
```

Additional resources

- **mount(8)** man page on your system

CHAPTER 18. PERSISTENTLY MOUNTING FILE SYSTEMS

As a system administrator, you can persistently mount file systems to configure non-removable storage.

18.1. THE /ETC/FSTAB FILE

Use the **/etc/fstab** configuration file to control persistent mount points of file systems. Each line in the **/etc/fstab** file defines a mount point of a file system.

It includes six fields separated by white space:

1. The block device identified by a persistent attribute or a path in the **/dev** directory.
2. The directory where the device will be mounted.
3. The file system on the device.
4. Mount options for the file system, which includes the **defaults** option to mount the partition at boot time with default options. The mount option field also recognizes the **systemd** mount unit options in the **x-systemd.*option*** format.
5. Backup option for the **dump** utility.
6. Check order for the **fsck** utility.

NOTE

The **systemd-fstab-generator** dynamically converts the entries from the **/etc/fstab** file to the **systemd-mount** units. The **systemd** auto mounts LVM volumes from **/etc/fstab** during manual activation unless the **systemd-mount** unit is masked.

NOTE

The **dump** utility used for backup of file systems has been removed in RHEL 9, and is available in the EPEL 9 repository.

Example 18.1. The /boot file system in /etc/fstab

Block device	Mount point	File system	Options	Backup	Check
UUID=ea74bbec-536d-490c-b8d9-5b40bbd7545b	**/boot**	**xfs**	**defaults**	**0**	**0**

The **systemd** service automatically generates mount units from entries in **/etc/fstab**.

Additional resources

- **fstab(5)** and **systemd.mount(5)** man pages on your system

18.2. ADDING A FILE SYSTEM TO /ETC/FSTAB

Configure persistent mount point for a file system in the **/etc/fstab** configuration file.

Procedure

1. Find out the UUID attribute of the file system:

```
$ lsblk --fs storage-device
```

   For example:

   Example 18.2. Viewing the UUID of a partition

```
$ lsblk --fs /dev/sda1

NAME FSTYPE LABEL UUID                                 MOUNTPOINT
sda1 xfs    Boot  ea74bbec-536d-490c-b8d9-5b40bbd7545b /boot
```

2. If the mount point directory does not exist, create it:

```
# mkdir --parents mount-point
```

3. As root, edit the **/etc/fstab** file and add a line for the file system, identified by the UUID.
   For example:

   Example 18.3. The /boot mount point in /etc/fstab

```
UUID=ea74bbec-536d-490c-b8d9-5b40bbd7545b /boot xfs defaults 0 0
```

4. Regenerate mount units so that your system registers the new configuration:

```
# systemctl daemon-reload
```

5. Try mounting the file system to verify that the configuration works:

```
# mount mount-point
```

Additional resources

- Overview of persistent naming attributes

CHAPTER 19. MOUNTING FILE SYSTEMS ON DEMAND

As a system administrator, you can configure file systems, such as NFS, to mount automatically on demand.

19.1. THE AUTOFS SERVICE

The **autofs** service can mount and unmount file systems automatically (on-demand), therefore saving system resources. It can be used to mount file systems such as NFS, AFS, SMBFS, CIFS, and local file systems.

One drawback of permanent mounting using the **/etc/fstab** configuration is that, regardless of how infrequently a user accesses the mounted file system, the system must dedicate resources to keep the mounted file system in place. This might affect system performance when, for example, the system is maintaining NFS mounts to many systems at one time.

An alternative to **/etc/fstab** is to use the kernel-based **autofs** service. It consists of the following components:

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

Additional resources

- **autofs(8)** man page on your system

19.2. THE AUTOFS CONFIGURATION FILES

This section describes the usage and syntax of configuration files used by the **autofs** service.

The master map file

The **autofs** service 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 the **/etc/autofs.conf** configuration file in conjunction with the Name Service Switch (NSS) mechanism.

All on-demand mount points must be configured in the master map. Mount point, host name, 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.

The master map file lists mount points controlled by **autofs**, 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; for example, **/mnt/data**.

map-file

The map source file, which contains a list of mount points and the file system location from which those mount points should be mounted.

options

If supplied, these apply to all entries in the given map, if they do not themselves have options specified.

Example 19.1. The /etc/auto.master file

The following is a sample line from **/etc/auto.master** file:

```
/mnt/data  /etc/auto.data
```

Map files

Map files configure the properties of individual on-demand mount points.

The automounter creates 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. If a timeout is specified, the directory is automatically unmounted if the directory is not accessed for the timeout period.

The general format of maps is similar to the master map. However, the options field appears 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*) can be followed by a space separated list of offset directories (subdirectory names each beginning with /) making them what is known as a multi-mount entry.

options

When supplied, these options are appended to the master map entry options, if any, or used instead of the master map options if the configuration entry **append_options** is set to **no**.

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.

Example 19.2. A map file

The following is a sample from a map file; for example, **/etc/auto.misc**:

```
payroll  -fstype=nfs4  personnel:/exports/payroll
sales    -fstype=xfs   :/dev/hda4
```

The first column in the 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. The third column indicates the source of the mount.

Following the given configuration, the **autofs** mount points will be **/home/payroll** and **/home/sales**. The **-fstype=** option is often omitted and is not needed if the file system is NFS, including mounts for NFSv4 if the system default is NFSv4 for NFS mounts.

Using the given configuration, if a process requires access to an **autofs** unmounted directory such as **/home/payroll/2006/July.sxc**, the **autofs** service automatically mounts the directory.

The amd map format

The **autofs** service recognizes map configuration in the **amd** format as well. This is useful if you want to reuse existing automounter configuration written for the **am-utils** service, which has been removed from Red Hat Enterprise Linux.

However, Red Hat recommends using the simpler **autofs** format described in the previous sections.

Additional resources

- **autofs(5)**, **autofs.conf(5)**, and **auto.master(5)** man pages on your system
- **/usr/share/doc/autofs/README.amd-maps** file

19.3. CONFIGURING AUTOFS MOUNT POINTS

Configure on-demand mount points by using the **autofs** service.

Prerequisites

- Install the **autofs** package:

```
# dnf install autofs
```

- Start and enable the **autofs** service:

```
# systemctl enable --now autofs
```

Procedure

1. Create a map file for the on-demand mount point, located at **/etc/auto.*identifier***. Replace *identifier* with a name that identifies the mount point.
2. In the map file, enter the mount point, options, and location fields as described in The autofs configuration files section.
3. Register the map file in the master map file, as described in The autofs configuration files section.
4. Allow the service to re-read the configuration, so it can manage the newly configured **autofs** mount:

```
# systemctl reload autofs.service
```

5. Try accessing content in the on-demand directory:

```
# ls automounted-directory
```

19.4. AUTOMOUNTING NFS SERVER USER HOME DIRECTORIES WITH AUTOFS SERVICE

Configure the **autofs** service to mount user home directories automatically.

Prerequisites

- The **autofs** package is installed.
- The **autofs** service is enabled and running.

Procedure

1. Specify the mount point and location of the map file by editing the **/etc/auto.master** file on a server on which you need to mount user home directories. To do so, add the following line into the **/etc/auto.master** file:

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

2. Create a map file with the name of **/etc/auto.home** on a server on which you need to mount user home directories, and edit the file with the following parameters:

   ```
   * -fstype=nfs,rw,sync host.example.com:/home/&
   ```

   You can skip ***fstype*** parameter, as it is ***nfs*** by default. For more information, see **autofs(5)** man page on your system.

3. Reload the **autofs** service:

   ```
   # systemctl reload autofs
   ```

19.5. OVERRIDING OR AUGMENTING AUTOFS SITE CONFIGURATION FILES

It is sometimes useful to override site defaults for a specific mount point on a client system.

Example 19.3. Initial conditions

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:

  ```
  +auto.master
  ```

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

```
/home auto.home
```

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

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

- The **autofs** configuration option **BROWSE_MODE** is set to **yes**:

```
BROWSE_MODE="yes"
```

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

Procedure

This section describes the examples of mounting home directories from a different server and augmenting **auto.home** with only selected entries.

Example 19.4. Mounting home directories from a different server

Given the preceding 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 needs to use the following **/etc/auto.master** map:

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

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

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

Because the automounter only processes the first occurrence of a mount point, the **/home** directory contains the content of **/etc/auto.home** instead of the NIS **auto.home** map.

Example 19.5. Augmenting auto.home with only selected entries

Alternatively, to augment the site-wide **auto.home** map with just a few entries:

1. 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 looks similar to:

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

2. With these NIS **auto.home** map conditions, listing the content of the **/home** directory outputs:

```
$ ls /home

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.

19.6. USING LDAP TO STORE AUTOMOUNTER MAPS

Configure **autofs** to store automounter maps in LDAP configuration rather than in **autofs** map files.

Prerequisites

- 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 **autofs** package.

Procedure

1. To configure LDAP access, modify the **/etc/openldap/ldap.conf** file. Ensure that the **BASE**, **URI**, and **schema** options are set appropriately for your site.

2. The most recently established schema for storing automount maps in LDAP is described by the **rfc2307bis** draft. To use this schema, set it in the **/etc/autofs.conf** configuration file by removing the comment characters from the schema definition. For example:

   Example 19.6. 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"
   ```

3. Ensure that all other schema entries are commented in the configuration. The **automountKey** attribute of the **rfc2307bis** schema replaces the **cn** attribute of the **rfc2307** schema. Following is an example of an LDAP Data Interchange Format (LDIF) configuration:

   Example 19.7. LDIF Configuration

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

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

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

# 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/&
```

Additional resources

- The **rfc2307bis** draft

19.7. USING SYSTEMD.AUTOMOUNT TO MOUNT A FILE SYSTEM ON DEMAND WITH /ETC/FSTAB

Mount a file system on demand using the automount systemd units when mount point is defined in **/etc/fstab**. You have to add an automount unit for each mount and enable it.

Procedure

1. Add desired fstab entry as documented in Persistently mounting file systems. For example:

```
/dev/disk/by-id/da875760-edb9-4b82-99dc-5f4b1ff2e5f4  /mount/point  xfs  defaults  0 0
```

2. Add **x-systemd.automount** to the options field of entry created in the previous step.
3. Load newly created units so that your system registers the new configuration:

```
# systemctl daemon-reload
```

4. Start the automount unit:

```
# systemctl start mount-point.automount
```

Verification

1. Check that ***mount-point.automount*** is running:

```
# systemctl status mount-point.automount
```

2. Check that automounted directory has desired content:

```
# ls /mount/point
```

Additional resources

- **systemd.automount(5)** and **systemd.mount(5)** man pages on your system
- Managing systemd

19.8. USING SYSTEMD.AUTOMOUNT TO MOUNT A FILE SYSTEM ON-DEMAND WITH A MOUNT UNIT

Mount a file system on-demand using the automount systemd units when mount point is defined by a mount unit. You have to add an automount unit for each mount and enable it.

Procedure

1. Create a mount unit. For example:

```
mount-point.mount
[Mount]
What=/dev/disk/by-uuid/f5755511-a714-44c1-a123-cfde0e4ac688
Where=/mount/point
Type=xfs
```

2. Create a unit file with the same name as the mount unit, but with extension **.automount**.

3. Open the file and create an **[Automount]** section. Set the **Where=** option to the mount path:

```
[Automount]
Where=/mount/point
[Install]
WantedBy=multi-user.target
```

4. Load newly created units so that your system registers the new configuration:

```
# systemctl daemon-reload
```

5. Enable and start the automount unit instead:

```
# systemctl enable --now mount-point.automount
```

Verification

1. Check that ***mount-point.automount*** is running:

```
# systemctl status mount-point.automount
```

2. Check that automounted directory has desired content:

```
# ls /mount/point
```

Additional resources

- **systemd.automount(5)** and **systemd.mount(5)** man pages on your system
- Managing systemd

CHAPTER 20. USING SSSD COMPONENT FROM IDM TO CACHE THE AUTOFS MAPS

The System Security Services Daemon (SSSD) is a system service to access remote service directories and authentication mechanisms. The data caching is useful in case of the slow network connection. To configure the SSSD service to cache the autofs map, follow the procedures below in this section.

20.1. CONFIGURING AUTOFS MANUALLY TO USE IDM SERVER AS AN LDAP SERVER

Configure **autofs** to use IdM server as an LDAP server.

Procedure

1. Edit the **/etc/autofs.conf** file to specify the schema attributes that **autofs** searches for:

```
#
# Other common LDAP naming
#
map_object_class = "automountMap"
entry_object_class = "automount"
map_attribute = "automountMapName"
entry_attribute = "automountKey"
value_attribute = "automountInformation"
```

NOTE

User can write the attributes in both lower and upper cases in the **/etc/autofs.conf** file.

2. Optional: Specify the LDAP configuration. There are two ways to do this. The simplest is to let the automount service discover the LDAP server and locations on its own:

```
ldap_uri = "ldap:///dc=example,dc=com"
```

This option requires DNS to contain SRV records for the discoverable servers.

Alternatively, explicitly set which LDAP server to use and the base DN for LDAP searches:

```
ldap_uri = "ldap://ipa.example.com"
search_base = "cn=location,cn=automount,dc=example,dc=com"
```

3. Edit the **/etc/autofs_ldap_auth.conf** file so that autofs allows client authentication with the IdM LDAP server.

   - Change **authrequired** to yes.

   - Set the principal to the Kerberos host principal for the IdM LDAP server, *host/FQDN@REALM*. The principal name is used to connect to the IdM directory as part of GSS client authentication.

```
<autofs_ldap_sasl_conf
```

```
usetls="no"
tlsrequired="no"
authrequired="yes"
authtype="GSSAPI"
clientprinc="host/server.example.com@EXAMPLE.COM"
/>
```

For more information about host principal, see Using canonicalized DNS host names in IdM .

If necessary, run **klist -k** to get the exact host principal information.

20.2. CONFIGURING SSSD TO CACHE AUTOFS MAPS

The SSSD service can be used to cache **autofs** maps stored on an IdM server without having to configure **autofs** to use the IdM server at all.

Prerequisites

- The **sssd** package is installed.

Procedure

1. Open the SSSD configuration file:

```
# vim /etc/sssd/sssd.conf
```

2. Add the **autofs** service to the list of services handled by SSSD.

```
[sssd]
domains = ldap
services = nss,pam,autofs
```

3. Create a new **[autofs]** section. You can leave this blank, because the default settings for an **autofs** service work with most infrastructures.

```
[nss]

[pam]

[sudo]

[autofs]

[ssh]

[pac]
```

For more information, see the **sssd.conf** man page on your system.

4. Optional: Set a search base for the **autofs** entries. By default, this is the LDAP search base, but a subtree can be specified in the **ldap_autofs_search_base** parameter.

```
[domain/EXAMPLE]
```

```
ldap_search_base = "dc=example,dc=com"
ldap_autofs_search_base = "ou=automount,dc=example,dc=com"
```

5. Restart SSSD service:

```
# systemctl restart sssd.service
```

6. Check the **/etc/nsswitch.conf** file, so that SSSD is listed as a source for automount configuration:

```
automount: sss files
```

7. Restart **autofs** service:

```
# systemctl restart autofs.service
```

8. Test the configuration by listing a user's **/home** directory, assuming there is a master map entry for **/home**:

```
# ls /home/userName
```

If this does not mount the remote file system, check the **/var/log/messages** file for errors. If necessary, increase the debug level in the **/etc/sysconfig/autofs** file by setting the **logging** parameter to **debug**.

CHAPTER 21. SETTING READ-ONLY PERMISSIONS FOR THE ROOT FILE SYSTEM

Sometimes, you need to mount the root file system (**/**) with read-only permissions. Example use cases include enhancing security or ensuring data integrity after an unexpected system power-off.

21.1. FILES AND DIRECTORIES THAT ALWAYS RETAIN WRITE PERMISSIONS

For the system to function properly, some files and directories need to retain write permissions. When the root file system is mounted in read-only mode, these files are mounted in RAM using the **tmpfs** temporary file system.

The default set of such files and directories is read from the **/etc/rwtab** file. Note that the **readonly-root** package is required to have this file present in your system.

```
dirs /var/cache/man
dirs /var/gdm
<content truncated>

empty /tmp
empty /var/cache/foomatic
<content truncated>

files /etc/adjtime
files /etc/ntp.conf
<content truncated>
```

Entries in the **/etc/rwtab** file follow this format:

```
copy-method    path
```

In this syntax:

- Replace *copy-method* with one of the keywords specifying how the file or directory is copied to tmpfs.
- Replace *path* with the path to the file or directory.

The **/etc/rwtab** file recognizes the following ways in which a file or directory can be copied to **tmpfs**:

empty

An empty path is copied to **tmpfs**. For example:

```
empty /tmp
```

dirs

A directory tree is copied to **tmpfs**, empty. For example:

```
dirs /var/run
```

files

A file or a directory tree is copied to **tmpfs** intact. For example:

```
files /etc/resolv.conf
```

The same format applies when adding custom paths to **/etc/rwtab.d/**.

21.2. CONFIGURING THE ROOT FILE SYSTEM TO MOUNT WITH READ-ONLY PERMISSIONS ON BOOT

With this procedure, the root file system is mounted read-only on all following boots.

Procedure

1. In the **/etc/sysconfig/readonly-root** file, set the **READONLY** option to **yes** to mount the file systems as read-only:

   ```
   READONLY=yes
   ```

2. Add the **ro** option in the root entry (**/**) in the **/etc/fstab** file:

   ```
   /dev/mapper/luks-c376919e...  /  xfs  x-systemd.device-timeout=0,ro  1  1
   ```

3. Enable the **ro** kernel option:

   ```
   # grubby --update-kernel=ALL --args="ro"
   ```

4. Ensure that the **rw** kernel option is disabled:

   ```
   # grubby --update-kernel=ALL --remove-args="rw"
   ```

5. If you need to add files and directories to be mounted with write permissions in the **tmpfs** file system, create a text file in the **/etc/rwtab.d/** directory and put the configuration there.
   For example, to mount the **/etc/example/file** file with write permissions, add this line to the **/etc/rwtab.d/example** file:

   ```
   files /etc/example/file
   ```

   IMPORTANT

   Changes made to files and directories in **tmpfs** do not persist across boots.

6. Reboot the system to apply the changes.

Troubleshooting

- If you mount the root file system with read-only permissions by mistake, you can remount it with read-and-write permissions again using the following command:

```
# mount -o remount,rw /
```

CHAPTER 22. LIMITING STORAGE SPACE USAGE ON XFS WITH QUOTAS

You can restrict the amount of disk space available to users or groups by implementing disk quotas. You can also define a warning level at which system administrators are informed before a user consumes too much disk space or a partition becomes full.

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. Group and project quotas are only mutually exclusive on older non-default XFS disk formats.

When managing on a per-directory or per-project basis, XFS manages the disk usage of directory hierarchies associated with a specific project.

22.1. DISK QUOTAS

In most computing environments, disk space is not infinite. The quota subsystem provides a mechanism to control usage of disk space.

You can configure disk quotas for individual users as well as user groups on the local file systems. This makes it possible to manage the space allocated for user-specific files (such as email) separately from the space allocated to the projects that a user works on. The quota subsystem warns users when they exceed their allotted limit, but allows some extra space for current work (hard limit/soft limit).

If quotas are implemented, you need to check if the quotas are exceeded and make sure the quotas are accurate. If users repeatedly exceed their quotas or consistently reach their soft limits, a system administrator can either help the user determine how to use less disk space or increase the user's disk quota.

You can set quotas to control:

- The number of consumed disk blocks.
- The number of inodes, which are data structures that contain information about files in UNIX file systems. Because inodes store file-related information, this allows control over the number of files that can be created.

22.2. THE `XFS_QUOTA` TOOL

You can use the **xfs_quota** tool to manage quotas on XFS file systems. In addition, you can use XFS file systems with limit enforcement turned off as an effective disk usage accounting system.

The XFS quota system differs from other file systems in a number of ways. Most importantly, XFS considers quota information as file system metadata and uses journaling to provide a higher level guarantee of consistency.

Additional resources

- **xfs_quota(8)** man page on your system

22.3. FILE SYSTEM QUOTA MANAGEMENT IN XFS

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. Group and project quotas are only mutually exclusive on older non-default XFS disk formats.

When managing on a per-directory or per-project basis, XFS manages the disk usage of directory hierarchies associated with a specific project.

22.4. ENABLING DISK QUOTAS FOR XFS

Enable disk quotas for users, groups, and projects on an XFS file system. Once quotas are enabled, the **xfs_quota** tool can be used to set limits and report on disk usage.

Procedure

1. Enable quotas for users:

   ```
   # mount -o uquota /dev/xvdb1 /xfs
   ```

   Replace **uquota** with **uqnoenforce** to allow usage reporting without enforcing any limits.

2. Enable quotas for groups:

   ```
   # mount -o gquota /dev/xvdb1 /xfs
   ```

   Replace **gquota** with **gqnoenforce** to allow usage reporting without enforcing any limits.

3. Enable quotas for projects:

   ```
   # mount -o pquota /dev/xvdb1 /xfs
   ```

   Replace **pquota** with **pqnoenforce** to allow usage reporting without enforcing any limits.

4. Alternatively, include the quota mount options in the **/etc/fstab** file. The following example shows entries in the **/etc/fstab** file to enable quotas for users, groups, and projects, respectively, on an XFS file system. These examples also mount the file system with read/write permissions:

   ```
   # vim /etc/fstab
   /dev/xvdb1    /xfs    xfs    rw,quota       0  0
   /dev/xvdb1    /xfs    xfs    rw,gquota      0  0
   /dev/xvdb1    /xfs    xfs    rw,prjquota    0  0
   ```

Additional resources

- **xfs(5)** and **xfs_quota(8)** man pages on your system

22.5. REPORTING XFS USAGE

Use the **xfs_quota** tool to set limits and report on disk usage. By default, **xfs_quota** is run interactively, and in basic mode. Basic mode subcommands simply report usage, and are available to all users.

Prerequisites

- Quotas have been enabled for the XFS file system. See Enabling disk quotas for XFS.

Procedure

1. Start the **xfs_quota** shell:

```
# xfs_quota
```

2. Show usage and limits for the given user:

```
xfs_quota> quota username
```

3. Show free and used counts for blocks and inodes:

```
xfs_quota> df
```

4. Run the help command to display the basic commands available with **xfs_quota**.

```
xfs_quota> help
```

5. Specify **q** to exit **xfs_quota**.

```
xfs_quota> q
```

Additional resources

- **xfs_quota(8)** man page on your system

22.6. MODIFYING XFS QUOTA LIMITS

Start the **xfs_quota** tool with the **-x** option to enable expert mode and run the administrator commands, which allow modifications to the quota system. The subcommands of this mode allow actual configuration of limits, and are available only to users with elevated privileges.

Prerequisites

- Quotas have been enabled for the XFS file system. See Enabling disk quotas for XFS.

Procedure

1. Start the **xfs_quota** shell with the **-x** option to enable expert mode:

```
# xfs_quota -x /path
```

2. Report quota information for a specific file system:

```
xfs_quota> report /path
```

For example, to display a sample quota report for **/home** (on **/dev/blockdevice**), use the command **report -h /home**. This displays 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 [------]
```

3. Modify quota limits:

```
xfs_quota> limit isoft=500m ihard=700m user
```

For example, 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.

4. Display the expert commands available with **xfs_quota -x**:

```
xfs_quota> help
```

Verification

- Verify that the quota limits have been modified:

```
xfs_quota> report -i -u
User quota on /home (/dev/loop0)
                        Inodes
User ID         Used       Soft       Hard    Warn/ Grace
---------- -------------------------------------------------
root              3          0          0     00 [------]
testuser            2        500        700     00 [------]
```

Additional resources

- **xfs_quota(8)** man page on your system

22.7. SETTING PROJECT LIMITS FOR XFS

Configure limits for project-controlled directories.

Procedure

1. Add the project-controlled directories to **/etc/projects**. For example, the following adds the **/var/log** path with a unique ID of 11 to **/etc/projects**. Your project ID can be any numerical value mapped to your project.

```
# echo 11:/var/log >> /etc/projects
```

2. Add project names to **/etc/projid** to map project IDs to project names. For example, the following associates a project called **logfiles** with the project ID of 11 as defined in the previous step.

```
# echo logfiles:11 >> /etc/projid
```

3. Initialize the project directory. For example, the following initializes the project directory **/var**:

```
# xfs_quota -x -c 'project -s logfiles' /var
```

4. Configure quotas for projects with initialized directories:

```
# xfs_quota -x -c 'limit -p bhard=1g logfiles' /var
```

Additional resources

- **xfs_quota(8)**, **projid(5)**, and **projects(5)** man pages on your system

CHAPTER 23. LIMITING STORAGE SPACE USAGE ON EXT4 WITH QUOTAS

You have to enable disk quotas on your system before you can assign them. You can assign disk quotas per user, per group or per project. However, if there is a soft limit set, you can exceed these quotas for a configurable period of time, known as the grace period.

23.1. INSTALLING THE QUOTA TOOL

You must install the **quota** RPM package to implement disk quotas.

Procedure

- Install the **quota** package:

```
# dnf install quota
```

23.2. ENABLING QUOTA FEATURE ON FILE SYSTEM CREATION

Enable quotas on file system creation.

Procedure

1. Enable quotas on file system creation:

```
# mkfs.ext4 -O quota /dev/sda
```

NOTE

Only user and group quotas are enabled and initialized by default.

2. Change the defaults on file system creation:

```
# mkfs.ext4 -O quota -E quotatype=usrquota:grpquota:prjquota /dev/sda
```

3. Mount the file system:

```
# mount /dev/sda
```

Additional resources

- **ext4(5)** man page on your system.

23.3. ENABLING QUOTA FEATURE ON EXISTING FILE SYSTEMS

Enable the quota feature on existing file system by using the **tune2fs** command.

Procedure

1. Unmount the file system:

```
# umount /dev/sda
```

2. Enable quotas on existing file system:

```
# tune2fs -O quota /dev/sda
```

> **NOTE**
>
> Only user and group quotas are initialized by default.

3. Change the defaults:

```
# tune2fs -Q usrquota,grpquota,prjquota /dev/sda
```

4. Mount the file system:

```
# mount /dev/sda
```

Additional resources

- **ext4(5)** man page on your system.

23.4. ENABLING QUOTA ENFORCEMENT

The quota accounting is enabled by default after mounting the file system without any additional options, but quota enforcement is not.

Prerequisites

- Quota feature is enabled and the default quotas are initialized.

Procedure

- Enable quota enforcement by **quotaon** for the user quota:

```
# mount /dev/sda /mnt
```

```
# quotaon /mnt
```

> **NOTE**
>
> The quota enforcement can be enabled at mount time using **usrquota**, **grpquota**, or **prjquota** mount options.
>
> ```
> # mount -o usrquota,grpquota,prjquota /dev/sda /mnt
> ```

- Enable user, group, and project quotas for all file systems:

```
# quotaon -vaugP
```

- If neither of the **-u**, **-g**, or **-P** options are specified, only the user quotas are enabled.
- If only **-g** option is specified, only group quotas are enabled.
- If only **-P** option is specified, only project quotas are enabled.

- Enable quotas for a specific file system, such as **/home**:

```
# quotaon -vugP /home
```

Additional resources

- **quotaon(8)** man page on your system

23.5. ASSIGNING QUOTAS PER USER

The disk quotas are assigned to users with the **edquota** command.

> **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.

Prerequisites

- User must exist prior to setting the user quota.

Procedure

1. Assign the quota for a user:

```
# edquota username
```

Replace *username* with the user to which you want to assign the quotas.

For example, if you enable a quota for the **/dev/sda** partition and execute the command **edquota testuser**, the following is displayed in the default editor configured on the system:

```
Disk quotas for user testuser (uid 501):
Filesystem   blocks   soft   hard   inodes   soft   hard
/dev/sda      44043      0      0    37418      0      0
```

2. Change the desired limits.
If any of the values are set to 0, limit is not set. Change them in the text editor.

For example, the following shows the soft and hard block limits for the testuser have been set to 50000 and 55000 respectively.

```
Disk quotas for user testuser (uid 501):
Filesystem   blocks   soft   hard   inodes   soft   hard
/dev/sda      44043  50000  55000    37418      0      0
```

- 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.

Verification

- Verify that the quota for the user has been set:

```
# quota -v testuser
Disk quotas for user testuser:
Filesystem  blocks  quota  limit  grace  files  quota  limit  grace
/dev/sda      1000*  1000   1000           0      0      0
```

23.6. ASSIGNING QUOTAS PER GROUP

You can assign quotas on a per-group basis.

Prerequisites

- Group must exist prior to setting the group quota.

Procedure

1. Set a group quota:

```
# edquota -g groupname
```

For example, to set a group quota for the **devel** group:

```
# 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/sda     440400     0     0   37418     0     0
```

2. Modify the limits and save the file.

Verification

- Verify that the group quota is set:

```
# quota -vg groupname
```

23.7. ASSIGNING QUOTAS PER PROJECT

You can assign quotas per project.

Prerequisites

- Project quota is enabled on your file system.

Procedure

1. Add the project-controlled directories to **/etc/projects**. For example, the following adds the **/var/log** path with a unique ID of 11 to **/etc/projects**. Your project ID can be any numerical value mapped to your project.

```
# echo 11:/var/log >> /etc/projects
```

2. Add project names to **/etc/projid** to map project IDs to project names. For example, the following associates a project called **Logs** with the project ID of 11 as defined in the previous step.

```
# echo Logs:11 >> /etc/projid
```

3. Set the desired limits:

```
# edquota -P 11
```

NOTE

You can choose the project either by its project ID (**11** in this case), or by its name (**Logs** in this case).

4. Using **quotaon**, enable quota enforcement:
See Enabling quota enforcement.

Verification

- Verify that the project quota is set:

```
# quota -vP 11
```

NOTE

You can verify either by the project ID, or by the project name.

Additional resources

- **edquota(8)**, **projid(5)**, and **projects(5)** man pages on your system

23.8. SETTING THE GRACE PERIOD FOR SOFT LIMITS

If a given quota has soft limits, you can edit the grace period, which is the amount of time for which a soft limit can be exceeded. You can set the grace period for users, groups, or projects.

Procedure

- Edit the grace period:

```
# edquota -t
```

> **IMPORTANT**
>
> While other **edquota** commands operate on quotas for a particular user, group, or project, the **-t** option operates on every file system with quotas enabled.

Additional resources

- **edquota(8)** man page on your system

23.9. TURNING FILE SYSTEM QUOTAS OFF

Use **quotaoff** to turn disk quota enforcement off on the specified file systems. Quota accounting stays enabled after executing this command.

Procedure

- To turn all user and group quotas off:

```
# quotaoff -vaugP
```

  - If neither of the **-u**, **-g**, or **-P** options are specified, only the user quotas are disabled.
  - If only **-g** option is specified, only group quotas are disabled.
  - If only **-P** option is specified, only project quotas are disabled.
  - The **-v** switch causes verbose status information to display as the command executes.

Additional resources

- **quotaoff(8)** man page on your system

23.10. REPORTING ON DISK QUOTAS

Create a disk quota report by using the **repquota** utility.

Procedure

1. Run the **repquota** command:

```
# repquota
```

For example, the command **repquota /dev/sda** produces this output:

```
*** Report for user quotas on device /dev/sda
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
```

2. View the disk usage report for all quota-enabled file systems:

```
# repquota -augP
```

The **--** symbol displayed after each user determines whether the block or inode limits have been exceeded. If either soft limit is exceeded, a **+** character appears in place of the corresponding **-** character. The first **-** character 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.

Additional resources

The **repquota(8)** man page for more information.

CHAPTER 24. DISCARDING UNUSED BLOCKS

You can perform or schedule discard operations on block devices that support them. The block discard operation communicates to the underlying storage which file system blocks are no longer in use by the mounted file system. Block discard operations allow SSDs to optimize garbage collection routines, and they can inform thinly-provisioned storage to repurpose unused physical blocks.

Requirements

- The block device underlying the file system must support physical discard operations. Physical discard operations are supported if the value in the **/sys/block/*<device>*/queue/discard_max_bytes** file is not zero.

24.1. TYPES OF BLOCK DISCARD OPERATIONS

You can run discard operations using different methods:

Batch discard

Is triggered explicitly by the user and discards all unused blocks in the selected file systems.

Online discard

Is specified at mount time and triggers in real time without user intervention. Online discard operations discard only blocks that are transitioning from the **used** to the **free** state.

Periodic discard

Are batch operations that are run regularly by a **systemd** service.

All types are supported by the XFS and ext4 file systems.

Recommendations

Red Hat recommends that you use batch or periodic discard.

Use online discard only if:

- the system’s workload is such that batch discard is not feasible, or
- online discard operations are necessary to maintain performance.

24.2. PERFORMING BATCH BLOCK DISCARD

You can perform a batch block discard operation to discard unused blocks on a mounted file system.

Prerequisites

- The file system is mounted.
- The block device underlying the file system supports physical discard operations.

Procedure

- Use the **fstrim** utility:
  - To perform discard only on a selected file system, use:

    ```
    # fstrim mount-point
    ```

- To perform discard on all mounted file systems, use:

```
# fstrim --all
```

If you execute the **fstrim** command on:

- a device that does not support discard operations, or
- a logical device (LVM or MD) composed of multiple devices, where any one of the device does not support discard operations,

the following message displays:

```
# fstrim /mnt/non_discard

fstrim: /mnt/non_discard: the discard operation is not supported
```

Additional resources

- **fstrim(8)** man page on your system

24.3. ENABLING ONLINE BLOCK DISCARD

You can perform online block discard operations to automatically discard unused blocks on all supported file systems.

Procedure

- Enable online discard at mount time:
  - When mounting a file system manually, add the **-o discard** mount option:

    ```
    # mount -o discard device mount-point
    ```

  - When mounting a file system persistently, add the **discard** option to the mount entry in the **/etc/fstab** file.

Additional resources

- **mount(8)** and **fstab(5)** man pages on your system

24.4. ENABLING ONLINE BLOCK DISCARD BY USING THE STORAGE RHEL SYSTEM ROLE

You can mount an XFS file system with the online block discard option to automatically discard unused blocks.

Prerequisites

- You have prepared the control node and the managed nodes .

- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.

Procedure

1. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  tasks:
    - name: Enable online block discard
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_volumes:
          - name: barefs
            type: disk
            disks:
              - sdb
            fs_type: xfs
            mount_point: /mnt/data
            mount_options: discard
```

   For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

2. Validate the playbook syntax:

```
$ ansible-playbook --syntax-check ~/playbook.yml
```

   Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

3. Run the playbook:

```
$ ansible-playbook ~/playbook.yml
```

Verification

- Verify that online block discard option is enabled:

```
# ansible managed-node-01.example.com -m command -a 'findmnt /mnt/data'
```

24.5. ENABLING PERIODIC BLOCK DISCARD

You can enable a **systemd** timer to regularly discard unused blocks on all supported file systems.

Procedure

- Enable and start the **systemd** timer:

```
# systemctl enable --now fstrim.timer
Created symlink /etc/systemd/system/timers.target.wants/fstrim.timer →
/usr/lib/systemd/system/fstrim.timer.
```

Verification

- Verify the status of the timer:

```
# systemctl status fstrim.timer
fstrim.timer - Discard unused blocks once a week
   Loaded: loaded (/usr/lib/systemd/system/fstrim.timer; enabled; vendor preset: disabled)
   Active: active (waiting) since Wed 2023-05-17 13:24:41 CEST; 3min 15s ago
  Trigger: Mon 2023-05-22 01:20:46 CEST; 4 days left
     Docs: man:fstrim

May 17 13:24:41 localhost.localdomain systemd[1]: Started Discard unused blocks once a
week.
```

CHAPTER 25. SETTING UP STRATIS FILE SYSTEMS

Stratis is a local storage-management solution for Red Hat Enterprise Linux. It is focused on simplicity, ease of use, and gives you access to advanced storage features.

Stratis runs as a service to manage pools of physical storage devices, simplifying local storage management with ease of use while helping you set up and manage complex storage configurations.

Stratis can help you with:

- Initial configuration of storage
- Making changes later
- Using advanced storage features

The central concept of Stratis is a storage pool. This pool is created from one or more local disks or partitions, and file systems are created from the pool. The pool enables features such as:

- File system snapshots
- Thin provisioning
- Caching
- Encryption

25.1. COMPONENTS OF A STRATIS FILE SYSTEM

Externally, Stratis presents the following file system components on the command line and through the API:

blockdev

Block devices, such as disks or disk partitions.

pool

Composed of one or more block devices.
A pool has a fixed total size, equal to the size of the block devices.

The pool contains most Stratis layers, such as the non-volatile data cache using the **dm-cache** target.

Stratis creates a **/dev/stratis/*my-pool*/** directory for each pool. This directory contains links to devices that represent Stratis file systems in the pool.

filesystem

Each pool can contain zero or more file systems. A pool containing file systems can store any number of files.
File systems are thinly provisioned and do not have a fixed total size. The actual size of a file system grows with the data stored on it. If the size of the data approaches the virtual size of the file system, Stratis grows the thin volume and the file system automatically.

The file systems are formatted with the XFS file system.

> **IMPORTANT**
>
> Stratis tracks information about file systems that it created which XFS is not aware of, and changes made using XFS do not automatically create updates in Stratis. Users must not reformat or reconfigure XFS file systems that are managed by Stratis.

Stratis creates links to file systems at the **/dev/stratis/*my-pool*/*my-fs*** path.

Stratis uses many Device Mapper devices, which appear in **dmsetup** listings and the **/proc/partitions** file. Similarly, the **lsblk** command output reflects the internal workings and layers of Stratis.

25.2. BLOCK DEVICES COMPATIBLE WITH STRATIS

Storage devices that can be used with Stratis.

Supported devices

Stratis pools have been tested to work on these types of block devices:

- LUKS
- LVM logical volumes
- MD RAID
- DM Multipath
- iSCSI
- HDDs and SSDs
- NVMe devices

25.3. INSTALLING STRATIS

Install the required packages for Stratis.

Procedure

1. Install packages that provide the Stratis service and command-line utilities:

```
# dnf install stratisd stratis-cli
```

2. To start the **stratisd** service and enable it to launch at boot:

```
# systemctl enable --now stratisd
```

Verification

- Verify that the **stratisd** service is enabled and is running:

```
# systemctl status stratisd
stratisd.service - Stratis daemon
Loaded: loaded (/usr/lib/systemd/system/stratisd.service; enabled; preset:>
```

```
Active: active (running) since Tue 2025-03-25 14:04:42 CET; 30min ago
Docs: man:stratisd(8)
Main PID: 24141 (stratisd)
Tasks: 22 (limit: 99365)
Memory: 10.4M
CPU: 1.436s
CGroup: /system.slice/stratisd.service
 └─24141 /usr/libexec/stratisd --log-level debug
```

25.4. CREATING AN UNENCRYPTED STRATIS POOL

You can create an unencrypted Stratis pool from one or more block devices.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- The block device on which you are creating a Stratis pool is not in use, unmounted, and is at least 1 GB in space.
- On the IBM Z architecture, the **/dev/dasd*** block devices must be partitioned. Use the partition device for creating the Stratis pool.
  For information about partitioning DASD devices, see Configuring a Linux instance on IBM Z .

> **NOTE**
>
> You can only encrypt a Stratis pool during creation, and not later.

Procedure

1. Erase any file system, partition table, or RAID signatures that exist on each block device that you want to use in the Stratis pool:

   ```
   # wipefs --all block-device
   ```

   The ***block-device*** value is the path to the block device; for example, **/dev/sdb**.

2. Create the new unencrypted Stratis pool on the selected block device:

   ```
   # stratis pool create my-pool block-device
   ```

   The ***block-device*** value is the path to an empty or wiped block device.

   You can also specify multiple block devices on a single line by using the following command:

   ```
   # stratis pool create my-pool block-device-1 block-device-2
   ```

Verification

- Verify that the new Stratis pool was created:

  ```
  # stratis pool list
  ```

25.5. CREATING AN UNENCRYPTED STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to create an unencrypted Stratis pool from one or more block devices.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- The block device on which you are creating a Stratis pool is not in use, unmounted, and is at least 1 GB in space.

> **NOTE**
>
> You cannot encrypt an unencrypted Stratis pool after it is created.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the menu button and select **Create Stratis pool**
4. In the **Name** field, enter a name for the Stratis pool.
5. Select the **Block devices** from which you want to create the Stratis pool.
6. Optional: If you want to specify the maximum size for each file system that is created in the pool, select **Manage filesystem sizes**.
7. Click **Create**.

Verification

- Go to the **Storage** section and verify that you can see the new Stratis pool in the **Devices** table.

25.6. CREATING AN ENCRYPTED STRATIS POOL USING A KEY IN THE KERNEL KEYRING

To secure your data, you can use the kernel keyring to create an encrypted Stratis pool from one or more block devices.

When you create an encrypted Stratis pool this way, the kernel keyring is used as the primary encryption mechanism. After subsequent system reboots this kernel keyring is used to unlock the encrypted Stratis pool.

When creating an encrypted Stratis pool from one or more block devices, note the following:

- Each block device is encrypted using the **cryptsetup** library and implements the **LUKS2** format.
- Each Stratis pool can either have a unique key or share the same key with other pools. These keys are stored in the kernel keyring.
- The block devices that comprise a Stratis pool must be either all encrypted or all unencrypted. It is not possible to have both encrypted and unencrypted block devices in the same Stratis pool.
- Block devices added to the data cache of an encrypted Stratis pool are automatically encrypted.

Prerequisites

- Stratis v2.1.0 or later is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- The block device on which you are creating a Stratis pool is not in use, unmounted, and is at least 1 GB in space.
- On the IBM Z architecture, the **/dev/dasd*** block devices must be partitioned. Use the partition in the Stratis pool.
  For information about partitioning DASD devices, see Configuring a Linux instance on IBM Z .

Procedure

1. Erase any file system, partition table, or RAID signatures that exist on each block device that you want to use in the Stratis pool:

   ```
   # wipefs --all block-device
   ```

   The ***block-device*** value is the path to the block device; for example, **/dev/sdb**.

2. If you have not set a key already, run the following command and follow the prompts to create a key set to use for the encryption:

   ```
   # stratis key set --capture-key key-description
   ```

   The ***key-description*** is a reference to the key that gets created in the kernel keyring. You will be prompted to enter a key value at the command-line. You can also place the key value in a file and use the **--keyfile-path** option instead of the **--capture-key** option.

3. Create the encrypted Stratis pool and specify the key description to use for the encryption:

   ```
   # stratis pool create --key-desc key-description my-pool block-device
   ```

   key-description

   References the key that exists in the kernel keyring, which you created in the previous step.

   my-pool

Specifies the name of the new Stratis pool.

block-device

Specifies the path to an empty or wiped block device.
You can also specify multiple block devices on a single line by using the following command:

```
# stratis pool create --key-desc key-description my-pool block-device-1 block-device-2
```

Verification

- Verify that the new Stratis pool was created:

```
# stratis pool list
```

25.7. CREATING AN ENCRYPTED STRATIS POOL USING CLEVIS

Starting with Stratis 2.4.0, you can create an encrypted pool using the Clevis mechanism by specifying Clevis options at the command line.

Prerequisites

- Stratis v2.3.0 or later is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- An encrypted Stratis pool is created. For more information, see Creating an encrypted Stratis pool using a key in the kernel keyring.
- Your system supports TPM 2.0.

Procedure

1. Erase any file system, partition table, or RAID signatures that exist on each block device that you want to use in the Stratis pool:

```
# wipefs --all block-device
```

   The ***block-device*** value is the path to the block device; for example, **/dev/sdb**.

2. Create the encrypted Stratis pool and specify the Clevis mechanism to use for the encryption:

```
# stratis pool create --clevis tpm2 my-pool block-device
```

tpm2

Specifies the Clevis mechanism to use.

my-pool

Specifies the name of the new Stratis pool.

block-device

Specifies the path to an empty or wiped block device.
Alternatively, use the Clevis tang server mechanism by using the following command:

```
# stratis pool create --clevis tang --tang-url my-url --thumbprint thumbprint my-pool block-device
```

tang

Specifies the Clevis mechanism to use.

my-url

Specifies the URL of the tang server.

thumbprint

References the thumbprint of the tang server.
You can also specify multiple block devices on a single line by using the following command:

```
# stratis pool create --clevis tpm2 my-pool block-device-1 block-device-2
```

Verification

- Verify that the new Stratis pool was created:

```
# stratis pool list
```

> **NOTE**
>
> You can also create an encrypted pool using both Clevis and keyring mechanisms by specifying both Clevis and keyring options at the same time during pool creation.

25.8. CREATING AN ENCRYPTED STRATIS POOL BY USING THE STORAGE RHEL SYSTEM ROLE

To secure your data, you can create an encrypted Stratis pool with the **storage** RHEL system role. In addition to a passphrase, you can use Clevis and Tang or TPM protection as an encryption method.

> **IMPORTANT**
>
> You can configure Stratis encryption only on the entire pool.

Prerequisites

- You have prepared the control node and the managed nodes .
- The account you use to connect to the managed nodes has **sudo** permissions for these nodes.
- You can connect to the Tang server. For more information, see Deploying a Tang server with SELinux in enforcing mode.

Procedure

1. Store your sensitive variables in an encrypted file:
    a. Create the vault:

```
$ ansible-vault create ~/vault.yml
New Vault password: <vault_password>
Confirm New Vault password: <vault_password>
```

b. After the **ansible-vault create** command opens an editor, enter the sensitive data in the ***<key>*: *<value>*** format:

```
luks_password: <password>
```

c. Save the changes, and close the editor. Ansible encrypts the data in the vault.

2. Create a playbook file, for example, **~/playbook.yml**, with the following content:

```
---
- name: Manage local storage
  hosts: managed-node-01.example.com
  vars_files:
    - ~/vault.yml
  tasks:
    - name: Create a new encrypted Stratis pool with Clevis and Tang
      ansible.builtin.include_role:
        name: redhat.rhel_system_roles.storage
      vars:
        storage_pools:
          - name: mypool
            disks:
              - sdd
              - sde
            type: stratis
            encryption: true
            encryption_password: "{{ luks_password }}"
            encryption_clevis_pin: tang
            encryption_tang_url: tang-server.example.com:7500
```

The settings specified in the example playbook include the following:

encryption_password

Password or passphrase used to unlock the LUKS volumes.

encryption_clevis_pin

Clevis method that you can use to encrypt the created pool. You can use **tang** and **tpm2**.

encryption_tang_url

URL of the Tang server.

For details about all variables used in the playbook, see the **/usr/share/ansible/roles/rhel-system-roles.storage/README.md** file on the control node.

3. Validate the playbook syntax:

```
$ ansible-playbook --ask-vault-pass --syntax-check ~/playbook.yml
```

Note that this command only validates the syntax and does not protect against a wrong but valid configuration.

4. Run the playbook:

```
$ ansible-playbook --ask-vault-pass ~/playbook.yml
```

Verification

- Verify that the pool was created with Clevis and Tang configured:

```
$ ansible managed-node-01.example.com -m command -a 'sudo stratis report'
...
                    "clevis_config": {
                        "thp": "j-G4ddvdbVfxpnUbgxlpbe3KutSKmcHttILAtAkMTNA",
                        "url": "tang-server.example.com:7500"
                    },
                    "clevis_pin": "tang",
                    "in_use": true,
                    "key_description": "blivet-mypool",
```

Additional resources

- Ansible vault

25.9. CREATING AN ENCRYPTED STRATIS POOL BY USING THE WEB CONSOLE

To secure your data, you can use the web console to create an encrypted Stratis pool from one or more block devices.

When creating an encrypted Stratis pool from one or more block devices, note the following:

- Each block device is encrypted using the cryptsetup library and implements the LUKS2 format.
- Each Stratis pool can either have a unique key or share the same key with other pools. These keys are stored in the kernel keyring.
- The block devices that comprise a Stratis pool must be either all encrypted or all unencrypted. It is not possible to have both encrypted and unencrypted block devices in the same Stratis pool.
- Block devices added to the data tier of an encrypted Stratis pool are automatically encrypted.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- Stratis v2.1.0 or later is installed and the the **stratisd** service is running.
- The block device on which you are creating a Stratis pool is not in use, unmounted, and is at least 1 GB in space.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. Click **Storage**.

3. In the **Storage** table, click the menu button and select **Create Stratis pool**

4. In the **Name** field, enter a name for the Stratis pool.

5. Select the **Block devices** from which you want to create the Stratis pool.

6. Select the type of encryption, you can use a passphrase, a Tang keyserver, or both:

   - Passphrase:

     i. Enter a passphrase.

     ii. Confirm the passphrase.

   - Tang keyserver:

     i. Enter the keyserver address. For more information, see Deploying a Tang server with SELinux in enforcing mode.

7. Optional: If you want to specify the maximum size for each file system that is created in pool, select **Manage filesystem sizes**.

8. Click **Create**.

Verification

- Go to the **Storage** section and verify that you can see the new Stratis pool in the **Devices** table.

25.10. RENAMING A STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to rename an existing Stratis pool.

Prerequisites

- You have installed the RHEL 9 web console.

- You have enabled the cockpit service.

- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

- Stratis is installed and the **stratisd** service is running.
  The web console detects and installs Stratis by default. However, for manually installing Stratis, see Installing Stratis.

- A Stratis pool is created.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the Stratis pool you want to rename.
4. On the **Stratis pool** page, click **edit** next to the **Name** field.
5. In the **Rename Stratis pool** dialog box, enter a new name.
6. Click **Rename**.

25.11. SETTING OVERPROVISIONING MODE IN STRATIS FILE SYSTEM

By default, every Stratis pool is overprovisioned meaning the logical file system size can exceed the physically allocated space. Stratis monitors the file system usage, and automatically increases the allocation by using available space when needed. However, if all the available space is already allocated and the pool is full, no additional space can be assigned to the file system.

NOTE

If the file system runs out of space, users might lose data. For applications where the risk of data loss outweighs the benefits of overprovisioning, this feature can be disabled.

Stratis continuously monitors the pool usage and reports the values using the D-Bus API. Storage administrators must monitor these values and add devices to the pool as needed to prevent it from reaching capacity.

Prerequisites

- Stratis is installed. For more information, see Installing Stratis.

Procedure

To set up the pool correctly, you have two possibilities:

1. Create a pool from one or more block devices to make the pool fully provisioned at the time of creation:

   ```
   # stratis pool create --no-overprovision pool-name /dev/sdb
   ```

   - By using the **--no-overprovision** option, the pool cannot allocate more logical space than actual available physical space.
2. Set overprovisioning mode in the existing pool:

   ```
   # stratis pool overprovision pool-name <yes|no>
   ```

   - If set to "yes", you enable overprovisioning to the pool. This means that the sum of the logical sizes of the Stratis file systems, supported by the pool, can exceed the amount of available data space. If the pool is overprovisioned and the sum of the logical sizes of all the file systems exceeds the space available on the pool, then the system cannot turn off overprovisioning and returns an error.

Verification

1. View the full list of Stratis pools:

```
# stratis pool list

Name       Total Physical                  Properties     UUID                                   Alerts
pool-name  1.42 TiB / 23.96 MiB / 1.42 TiB  ~Ca,~Cr,~Op    cb7cb4d8-9322-4ac4-a6fd-
eb7ae9e1e540
```

2. Check if there is an indication of the pool overprovisioning mode flag in the **stratis pool list** output. The " ~ " is a math symbol for "NOT", so **~Op** means no-overprovisioning.

3. Optional: Check overprovisioning on a specific pool:

```
# stratis pool overprovision pool-name yes

# stratis pool list

Name         Total Physical                  Properties     UUID                                   Alerts
pool-name    1.42 TiB / 23.96 MiB / 1.42 TiB   ~Ca,~Cr,~Op    cb7cb4d8-9322-4ac4-a6fd-
eb7ae9e1e540
```

25.12. BINDING A STRATIS POOL TO NBDE

Binding an encrypted Stratis pool to Network Bound Disk Encryption (NBDE) requires a Tang server. When a system containing the Stratis pool reboots, it connects with the Tang server to automatically unlock the encrypted pool without you having to provide the kernel keyring description.

NOTE

Binding a Stratis pool to a supplementary Clevis encryption mechanism does not remove the primary kernel keyring encryption.

Prerequisites

- Stratis v2.3.0 or later is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- An encrypted Stratis pool is created, and you have the key description of the key that was used for the encryption. For more information, see Creating an encrypted Stratis pool using a key in the kernel keyring.
- You can connect to the Tang server. For more information, see Deploying a Tang server with SELinux in enforcing mode.

Procedure

- Bind an encrypted Stratis pool to NBDE:

```
# stratis pool bind nbde --trust-url my-pool tang-server
```

my-pool

Specifies the name of the encrypted Stratis pool.

tang-server

Specifies the IP address or URL of the Tang server.

Additional resources

- Configuring automated unlocking of encrypted volumes using policy-based decryption

25.13. BINDING A STRATIS POOL TO TPM

When you bind an encrypted Stratis pool to the Trusted Platform Module (TPM) 2.0, the system containing the pool reboots, and the pool is automatically unlocked without you having to provide the kernel keyring description.

Prerequisites

- Stratis v2.3.0 or later is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- An encrypted Stratis pool is created, and you have the key description of the key that was used for the encryption. For more information, see Creating an encrypted Stratis pool using a key in the kernel keyring.
- Your system supports TPM 2.0.

Procedure

- Bind an encrypted Stratis pool to TPM:

```
# stratis pool bind tpm my-pool
```

my-pool

Specifies the name of the encrypted Stratis pool.

key-description

References the key that exists in the kernel keyring, which was generated when you created the encrypted Stratis pool.

25.14. UNLOCKING AN ENCRYPTED STRATIS POOL WITH KERNEL KEYRING

After a system reboot, your encrypted Stratis pool or the block devices that comprise it might not be visible. You can unlock the pool using the kernel keyring that was used to encrypt the pool.

Prerequisites

- Stratis v2.1.0 is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- An encrypted Stratis pool is created. For more information, see Creating an encrypted Stratis pool using a key in the kernel keyring.

Procedure

1. Re-create the key set using the same key description that was used previously:

   ```
   # stratis key set --capture-key key-description
   ```

   key-description references the key that exists in the kernel keyring, which was generated when you created the encrypted Stratis pool.

2. Verify that the Stratis pool is visible:

   ```
   # stratis pool list
   ```

25.15. UNBINDING A STRATIS POOL FROM SUPPLEMENTARY ENCRYPTION

When you unbind an encrypted Stratis pool from a supported supplementary encryption mechanism, the primary kernel keyring encryption remains in place. This is not true for pools that are created with Clevis encryption from the start.

Prerequisites

- Stratis v2.3.0 or later is installed on your system. For more information, see Installing Stratis.
- An encrypted Stratis pool is created. For more information, see Creating an encrypted Stratis pool using a key in the kernel keyring.
- The encrypted Stratis pool is bound to a supported supplementary encryption mechanism.

Procedure

- Unbind an encrypted Stratis pool from a supplementary encryption mechanism:

  ```
  # stratis pool unbind clevis my-pool
  ```

  my-pool specifies the name of the Stratis pool you want to unbind.

Additional resources

- Binding an encrypted Stratis pool to NBDE
- Binding an encrypted Stratis pool to TPM

25.16. STARTING AND STOPPING STRATIS POOL

You can start and stop Stratis pools. This gives you the option to disassemble or bring down all the objects that were used to construct the pool, such as file systems, cache devices, thin pool, and encrypted devices. Note that if the pool actively uses any device or file system, it might issue a warning and not be able to stop.

The stopped state is recorded in the pool’s metadata. These pools do not start on the following boot, until the pool receives a start command.

Prerequisites

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- An unencrypted or an encrypted Stratis pool is created. For more information, see Creating an unencrypted Stratis pool or Creating an encrypted Stratis pool using a key in the kernel keyring .

Procedure

- Use the following command to stop the Stratis pool. This tears down the storage stack but leaves all metadata intact:

```
# stratis pool stop --name pool-name
```

- Use the following command to start the Stratis pool. The **--unlock-method** option specifies the method of unlocking the pool if it is encrypted:

```
# stratis pool start --unlock-method <keyring|clevis> --name pool-name
```

> **NOTE**
>
> You can start the pool by using either the pool name or the pool UUID.

Verification

- Use the following command to list all active pools on the system:

```
# stratis pool list
```

- Use the following command to list all the stopped pools:

```
# stratis pool list --stopped
```

- Use the following command to view detailed information for a stopped pool. If the UUID is specified, the command prints detailed information about the pool corresponding to the UUID:

```
# stratis pool list --stopped --uuid UUID
```

25.17. CREATING A STRATIS FILE SYSTEM

Create a Stratis file system on an existing Stratis pool.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- A Stratis pool is created. For more information, see Creating an unencrypted Stratis pool or using a key in the kernel keyring .

Procedure

1. Create a Stratis file system on a pool:

```
# stratis filesystem create --size number-and-unit my-pool my-fs
```

number-and-unit

Specifies the size of a file system. The specification format must follow the standard size specification format for input, that is B, KiB, MiB, GiB, TiB or PiB.

my-pool

Specifies the name of the Stratis pool.

my-fs

Specifies an arbitrary name for the file system.
For example:

Example 25.1. Creating a Stratis file system

```
# stratis filesystem create --size 10GiB pool1 filesystem1
```

2. Set a size limit of a file system:

```
# stratis filesystem create --size number-and-unit --size-limit number-and-unit my-pool my-fs
```

NOTE

This option is available starting with Stratis 3.6.0.

You can also remove the size limit later, if needed:

```
# stratis filesystem unset-size-limit my-pool my-fs
```

Verification

- List file systems within the pool to check if the Stratis file system is created:

```
# stratis fs list my-pool
```

Additional resources

- Mounting a Stratis file system

25.18. CREATING A FILE SYSTEM ON A STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to create a file system on an existing Stratis pool.

Prerequisites

- You have installed the RHEL 9 web console.

- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **stratisd** service is running.
- A Stratis pool is created.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. Click the Stratis pool on which you want to create a file system.
4. On the **Stratis pool** page, scroll to the **Stratis filesystems** section and click **Create new filesystem**.
5. Enter a name for the file system.
6. Enter a mount point for the file system.
7. Select the mount option.
8. In the **At boot** drop-down menu, select when you want to mount your file system.
9. Create the file system:
   - If you want to create and mount the file system, click **Create and mount**.
   - If you want to only create the file system, click **Create only**.

Verification

- The new file system is visible on the **Stratis pool** page under the **Stratis filesystems** tab.

25.19. MOUNTING A STRATIS FILE SYSTEM

Mount an existing Stratis file system to access the content.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- A Stratis file system is created. For more information, see Creating a Stratis file system .

Procedure

- To mount the file system, use the entries that Stratis maintains in the **/dev/stratis/** directory:

  ```
  # mount /dev/stratis/my-pool/my-fs mount-point
  ```

The file system is now mounted on the *mount-point* directory and ready to use.

> **NOTE**
>
> Unmount all file systems belonging to a pool before stopping it. The pool will not stop if any file system is still mounted.

25.20. SETTING UP NON-ROOT STRATIS FILE SYSTEMS IN /ETC/FSTAB USING A SYSTEMD SERVICE

You can manage setting up non-root file systems in **/etc/fstab** using a systemd service.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- A Stratis file system is created. For more information, see Creating a Stratis file system .

Procedure

- As root, edit the **/etc/fstab** file and add a line to set up non-root file systems:

  ```
  /dev/stratis/my-pool/my-fs mount-point xfs defaults,x-systemd.requires=stratis-fstab-setup@pool-uuid.service,x-systemd.after=stratis-fstab-setup@pool-uuid.service dump-value fsck_value
  ```

> **IMPORTANT**
>
> Persistently mounting a Stratis filesystem from an encrypted Stratis pool can cause the boot process to stop until a password is provided. If the pool is encrypted using any unattended mechanism, for example, NBDE or TPM2, the Stratis pool will be unlocked automatically. If not, the user will need to enter a password in the console.

Additional resources

- Persistently mounting file systems

CHAPTER 26. EXTENDING A STRATIS POOL WITH ADDITIONAL BLOCK DEVICES

You can attach additional block devices to a Stratis pool to provide more storage capacity for Stratis file systems. You can do it manually or by using the web console.

26.1. ADDING BLOCK DEVICES TO A STRATIS POOL

You can add one or more block devices to a Stratis pool.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- The block device on which you are creating a Stratis pool is not in use, unmounted, and is at least 1 GB in space.

Procedure

- To add one or more block devices to the pool, use:

```
# stratis pool add-data my-pool device-1 device-2 device-n
```

Additional resources

- **stratis(8)** man page on your system

26.2. ADDING A BLOCK DEVICE TO A STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to add a block device to an existing Stratis pool. You can also add caches as a block device.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **stratisd** service is running.
- A Stratis pool is created.
- The block device on which you are creating a Stratis pool is not in use, unmounted, and is at least 1 GB in space.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the Stratis pool to which you want to add a block device.
4. On the **Stratis pool** page, click **Add block devices** and select the **Tier** where you want to add a block device as data or cache.
5. If you are adding the block device to a Stratis pool that is encrypted with a passphrase, enter the passphrase.
6. Under **Block devices**, select the devices you want to add to the pool.
7. Click **Add**.

CHAPTER 27. MONITORING STRATIS FILE SYSTEMS

As a Stratis user, you can view information about Stratis file systems on your system to monitor their state and free space.

27.1. DISPLAYING INFORMATION ABOUT STRATIS FILE SYSTEMS

You can list statistics about your Stratis file systems, such as the total, used, and free size or file systems and block devices belonging to a pool, by using the **stratis** utility.

The size of an XFS file system is the total amount of user data that it can manage. On a thinly provisioned Stratis pool, a Stratis file system can appear to have a size that is larger than the space allocated to it. The XFS file system is sized to match this apparent size, which means it is usually larger than the allocated space. Standard Linux utilities, such as df, report the size of the XFS file system. This value generally overestimates the space required by the XFS file system and hence the space allocated for it by Stratis.

IMPORTANT

Regularly monitor the usage of your overprovisioned Stratis pools. If a file system usage approaches the allocated space, Stratis automatically increases the allocation using available space in the pool. However, if all the available space is already allocated and the pool is full, no additional space can be assigned causing the file system to run out of space. This may lead to the risk of data loss in the application using the Stratis file system.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, See Installing Stratis.

Procedure

- To display information about all **block devices** used for Stratis on your system:

```
# stratis blockdev
Pool Name   Device Node  Physical Size  Tier UUID
my-pool     /dev/sdb     9.10 TiB       Data    ec9fb718-f83c-11ef-861e-7446a09dccfb
```

- To display information about all Stratis **pools** on your system:

```
# stratis pool

Name     Total/Used/Free               Properties  UUID                            Alerts
my-pool  8.00 GiB / 800.99 MiB / 7.22 GiB  -Ca,-Cr,Op   e22772c2-afe9-446c-9be5-
2f78f682284e  WS001
```

- To display information about all Stratis **file systems** on your system:

```
# stratis filesystem

Pool Filesystem  Total/Used/Free/Limit            Device               UUID
Spool1  sfs1  1 TiB / 546 MiB / 1023.47 GiB / None  /dev/stratis/spool1/sfs1   223265f5-8f17-
4cc2-bf12-c3e9e71ff7bf
```

You can also display detailed information about a Stratis file system on your system by specifying the file system name or UUID:

```
# stratis filesystem list my-pool --name my-fs

UUID: 47255008-9bc7-4bd2-8294-e9d25cd9e7ba
Name: my-fs
Pool: my-pool
Device: /dev/stratis/my-pool/my-fs
Created: Nov 08 2018 08:03
Snapshot origin: None
Sizes:
 Logical size of thin device: 1 TiB
 Total used (including XFS metadata): 546 MiB
 Free: 1023.47 GiB
 Size Limit: None
```

Additional resources

- **stratis(8)** man page on your system

27.2. VIEWING A STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to view an existing Stratis pool and the file systems it contains.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **stratisd** service is running.
- You have an existing Stratis pool.

Procedure

1. Log in to the RHEL 9 web console.
2. Click **Storage**.
3. In the **Storage** table, click the Stratis pool you want to view.
   The Stratis pool page displays all the information about the pool and the file systems that you created in the pool.

CHAPTER 28. USING SNAPSHOTS ON STRATIS FILE SYSTEMS

You can use snapshots on Stratis file systems to capture file system state at arbitrary times and restore it in the future.

28.1. CHARACTERISTICS OF STRATIS SNAPSHOTS

In Stratis, a snapshot is a regular Stratis file system created as a copy of another Stratis file system.

The current snapshot implementation in Stratis is characterized by the following:

- A snapshot of a file system is another file system.
- A snapshot and its origin are not linked in lifetime. A snapshotted file system can live longer than the file system it was created from.
- A file system does not have to be mounted to create a snapshot from it.
- Each snapshot uses around half a gigabyte of actual backing storage, which is needed for the XFS log.

28.2. CREATING A STRATIS SNAPSHOT

You can create a Stratis file system as a snapshot of an existing Stratis file system.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- You have created a Stratis file system. For more information, see Creating a Stratis file system.

Procedure

- Create a Stratis snapshot:

```
# stratis fs snapshot my-pool my-fs my-fs-snapshot
```

A snapshot is a first class Stratis file system. You can create multiple Stratis snapshots. These include snapshots of a single origin file system or another snapshot file system. If a file system is a snapshot, then its **origin** field will display the UUID of its origin file system in the detailed file system listing.

Additional resources

- **stratis(8)** man page on your system

28.3. ACCESSING THE CONTENT OF A STRATIS SNAPSHOT

You can mount a snapshot of a Stratis file system to make it accessible for read and write operations.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- You have created a Stratis snapshot. For more information, see Creating a Stratis snapshot .

Procedure

- To access the snapshot, mount it as a regular file system from the **/dev/stratis/*my-pool*/** directory:

```
# mount /dev/stratis/my-pool/my-fs-snapshot mount-point
```

Additional resources

- Mounting a Stratis file system
- **mount(8)** man page on your system

28.4. REVERTING A STRATIS FILE SYSTEM TO A PREVIOUS SNAPSHOT

You can revert the content of a Stratis file system to the state captured in a Stratis snapshot.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- You have created a Stratis snapshot. For more information, see Creating a Stratis snapshot .

Procedure

1. Optional: Back up the current state of the file system to be able to access it later:

```
# stratis filesystem snapshot my-pool my-fs my-fs-backup
```

2. Schedule a revert of your file system to the previously taken snapshot:

```
# stratis filesystem schedule-revert my-pool my-fs-snapshot
```

3. Optional: Run the following to check if the revert is scheduled successfully:

```
# stratis filesystem list my-pool --name my-fs-snapshot
UUID: b14987eb-b735-4c68-8962-f53f6b644cbc
Name: my-fs-snapshot
Pool: my-pool

Device: /dev/stratis/p1/my-fs-snapshot

Created: Mar 18 2025 12:29

Snapshot origin: f5a881b1-299d-4147-8ead-b4a56c623692
Revert scheduled: Yes
```

```
Sizes:
Logical size of thin device: 1 TiB
Total used (including XFS metadata): 5.42 GiB
Free: 1018.58 GiB
```

NOTE

It is not possible to schedule more than one revert operation into the same origin filesystem. Also, if you try to destroy either the origin file system, or the snapshot to which the revert is scheduled, the destroy operation fails.

You can also cancel the revert operation any time before you restart the pool:

```
# stratis filesystem cancel-revert my-pool my-fs-snapshot
```

You can run the following to check if the cancellation is scheduled successfully:

```
# stratis filesystem list my-pool --name my-fs-snapshot
UUID: b14987eb-b735-4c68-8962-f53f6b644cbc
Name: my-fs-snapshot
Pool: my-pool

Device: /dev/stratis/p1/my-fs-snapshot

Created: Mar 18 2025 12:29

Snapshot origin: f5a881b1-299d-4147-8ead-b4a56c623692
Revert scheduled: No

Sizes:
Logical size of thin device: 1 TiB
Total used (including XFS metadata): 5.42 GiB
Free: 1018.58 GiB

Size Limit: None
```

If not cancelled, the scheduled revert will proceed when you restart the pool:

```
# stratis pool stop --name my-pool
# stratis pool start --name my-pool
```

Verification

1. List the file system belonging to the pool:

```
# stratis filesystem list my-pool
```

The **my-fs-snapshot** now does not appear in the list of file systems in the pool as it is reverted to the previously copied **my-fs-snapshot** state. The content of the file system named **my-fs** is now identical to the snapshot **my-fs-snapshot**.

Additional resources

- **stratis(8)** man page on your system

28.5. REMOVING A STRATIS SNAPSHOT

You can remove a Stratis snapshot from a pool. Data on the snapshot are lost.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information,see Installing Stratis.
- You have created a Stratis snapshot. For more information, see Creating a Stratis snapshot .

Procedure

1. Unmount the snapshot:

```
# umount /dev/stratis/my-pool/my-fs-snapshot
```

2. Destroy the snapshot:

```
# stratis filesystem destroy my-pool my-fs-snapshot
```

Additional resources

- **stratis(8)** man page on your system

CHAPTER 29. REMOVING STRATIS FILE SYSTEMS

You can remove an existing Stratis file system or pool. Once a Stratis file system or pool is removed, it cannot be recovered.

29.1. REMOVING A STRATIS FILE SYSTEM

You can remove an existing Stratis file system. Data stored on it are lost.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- You have created a Stratis file system. For more information, see Creating a Stratis file system .

Procedure

1. Unmount the file system:

```
# umount /dev/stratis/my-pool/my-fs
```

2. Destroy the file system:

```
# stratis filesystem destroy my-pool my-fs
```

Verification

- Verify that the file system no longer exists:

```
# stratis filesystem list my-pool
```

Additional resources

- **stratis(8)** man page on your system

29.2. DELETING A FILE SYSTEM FROM A STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to delete a file system from an existing Stratis pool.

> **NOTE**
>
> Deleting a Stratis pool file system erases all the data it contains.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.

- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- Stratis is installed and the **stratisd** service is running..
  The web console detects and installs Stratis by default. However, for manually installing Stratis, see Installing Stratis.
- You have an existing Stratis pool and a file system is created on the Stratis pool.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the Stratis pool from which you want to delete a file system.
4. On the **Stratis pool** page, scroll to the **Stratis filesystems** section and click the menu button ⋮ for the file system you want to delete.
5. From the drop-down menu, select **Delete**.
6. In the **Confirm deletion** dialog box, click **Delete**.

29.3. REMOVING A STRATIS POOL

You can remove an existing Stratis pool. Data stored on it are lost.

Prerequisites

- Stratis is installed and the **stratisd** service is running. For more information, see Installing Stratis.
- You have created a Stratis pool:
  - To create an unencrypted pool, see Creating an unencrypted Stratis pool .
  - To create an encrypted pool, see Creating an encrypted Stratis pool using a key in the kernel keyring.

Procedure

1. List file systems on the pool:

   ```
   # stratis filesystem list my-pool
   ```

2. Unmount all file systems on the pool:

   ```
   # umount /dev/stratis/my-pool/my-fs-1 \
            /dev/stratis/my-pool/my-fs-2 \
            /dev/stratis/my-pool/my-fs-n
   ```

3. Destroy the file systems:

```
# stratis filesystem destroy my-pool my-fs-1 my-fs-2
```

4. Destroy the pool:

```
# stratis pool destroy my-pool
```

Verification

- Verify that the pool no longer exists:

```
# stratis pool list
```

Additional resources

- **stratis(8)** man page on your system

29.4. DELETING A STRATIS POOL BY USING THE WEB CONSOLE

You can use the web console to delete an existing Stratis pool.

> **NOTE**
>
> Deleting a Stratis pool erases all the data it contains.

Prerequisites

- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The **stratisd** service is running.
- You have an existing Stratis pool.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click **Storage**.
3. In the **Storage** table, click the menu button ⋮ for the Stratis pool you want to delete.
4. From the drop-down menu, select **Delete pool**.
5. In the **Permanently delete pool** dialog box, click **Delete**.

CHAPTER 30. GETTING STARTED WITH AN EXT4 FILE SYSTEM

As a system administrator, you can create, mount, resize, backup, and restore an ext4 file system. The ext4 file system is a scalable extension of the ext3 file system. With Red Hat Enterprise Linux 9, it can support a maximum individual file size of **16** terabytes, and file system to a maximum of **50** terabytes.

30.1. FEATURES OF AN EXT4 FILE SYSTEM

Following are the features of an ext4 file system:

- Using extents: The ext4 file system uses extents, which improves performance when using large files and reduces metadata overhead for large files.
- Ext4 labels unallocated block groups and inode table sections accordingly, which allows the block groups and table sections to be skipped during a file system check. It leads to a quick file system check, which becomes more beneficial as the file system grows in size.
- Metadata checksum: By default, this feature is enabled in Red Hat Enterprise Linux 9.
- Allocation features of an ext4 file system:
  - Persistent pre-allocation
  - Delayed allocation
  - Multi-block allocation
  - Stripe-aware allocation
- 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). For more information, see the Red Hat Knowledgebase solution Is the EXT journaling option "data=writeback" supported in RHEL?.

- Subsecond timestamps - This gives timestamps to the subsecond.

Additional resources

- **ext4** man page on your system

30.2. CREATING AN EXT4 FILE SYSTEM

As a system administrator, you can create an ext4 file system on a block device using **mkfs.ext4** command.

Prerequisites

- A partition on your disk. For information about creating MBR or GPT partitions, see Creating a partition table on a disk with parted.
- Alternatively, use an LVM or MD volume.

Procedure

1. To create an ext4 file system:
    - For a regular-partition device, an LVM volume, an MD volume, or a similar device, use the following command:

      ```
      # mkfs.ext4 /dev/block_device
      ```

      Replace /dev/*block_device* with the path to a block device.

      For example, **/dev/sdb1**, **/dev/disk/by-uuid/05e99ec8-def1-4a5e-8a9d-5945339ceb2a**, or **/dev/my-volgroup/my-lv**. In general, the default options are optimal for most usage scenarios.
    - 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 enhances the performance of an ext4 file system. 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/block_device
      ```

      In the given example:
        - 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.

   > **NOTE**
   >
   > - To specify a UUID when creating a file system:
   >
   >   ```
   >   # mkfs.ext4 -U UUID /dev/block_device
   >   ```
   >
   >   Replace *UUID* with the UUID you want to set: for example, **7cd65de3-e0be-41d9-b66d-96d749c02da7**.
   >
   >   Replace /dev/*block_device* with the path to an ext4 file system to have the UUID added to it: for example, **/dev/sda8**.
   > - To specify a label when creating a file system:
   >
   >   ```
   >   # mkfs.ext4 -L label-name /dev/block_device
   >   ```

2. To view the created ext4 file system:

   ```
   # blkid
   ```

Additional resources

- **ext4** and **mkfs.ext4** man pages on your system

30.3. MOUNTING AN EXT4 FILE SYSTEM

As a system administrator, you can mount an ext4 file system using the **mount** utility.

Prerequisites

- An ext4 file system. For information about creating an ext4 file system, see Creating an ext4 file system.

Procedure

1. To create a mount point to mount the file system:

   ```
   # mkdir /mount/point
   ```

   Replace */mount/point* with the directory name where mount point of the partition must be created.

2. To mount an ext4 file system:

   - To mount an ext4 file system with no extra options:

     ```
     # mount /dev/block_device /mount/point
     ```

   - To mount the file system persistently, see Persistently mounting file systems.

3. To view the mounted file system:

   ```
   # df -h
   ```

Additional resources

- **mount**, **ext4**, and **fstab** man pages on your system
- Mounting file systems

30.4. RESIZING AN EXT4 FILE SYSTEM

As a system administrator, you can resize an ext4 file system using the **resize2fs** utility. 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 (sectors) - **512** byte sectors
- K (kilobytes) - **1,024** bytes
- M (megabytes) - **1,048,576** bytes
- G (gigabytes) - **1,073,741,824** bytes

- T (terabytes) - **1,099,511,627,776** bytes

Prerequisites

- An ext4 file system. For information about creating an ext4 file system, see Creating an ext4 file system.
- An underlying block device of an appropriate size to hold the file system after resizing.

Procedure

1. To resize an ext4 file system, take the following steps:
   - To shrink and grow the size of an unmounted ext4 file system:

     ```
     # umount /dev/block_device
     # e2fsck -f /dev/block_device
     # resize2fs /dev/block_device size
     ```

     Replace */dev/block_device* with the path to the block device, for example **/dev/sdb1**.

     Replace *size* with the required resize value using **s**, **K**, **M**, **G**, and **T** suffixes.

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

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

     NOTE

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

2. To view the resized file system:

   ```
   # df -h
   ```

Additional resources

- **resize2fs**, **e2fsck**, and **ext4** man pages on your system

30.5. COMPARISON OF TOOLS USED WITH EXT4 AND XFS

This section compares which tools to use to accomplish common tasks on the ext4 and XFS file systems.

Task	ext4	XFS
Create a file system	**mkfs.ext4**	**mkfs.xfs**
File system check	**e2fsck**	**xfs_repair**

Task	ext4	XFS
Resize 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**
Back up a file system	**tar** and **rsync**	**xfsdump** and **xfsrestore**
Quota management	**quota**	**xfs_quota**
File mapping	**filefrag**	**xfs_bmap**

NOTE

If you want a complete client-server solution for backups over network, you can use **bacula** backup utility that is available in RHEL 9. For more information about Bacula, see Bacula backup solution.