Red Hat Enterprise Linux 9

Managing storage devices

Configuring and managing local and remote storage devices

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Abstract

Red Hat Enterprise Linux (RHEL) provides several local and remote storage options. With the available storage options, you can perform the following tasks: Create disk partitions according to your requirements. Use disk encryption to protect the data on a block device. Create a Redundant Array of Independent Disks (RAID) to store data across multiple drives and avoid data loss. Use iSCSI and NVMe over Fabrics to access storage over a network. Set up Stratis to manage pools of physical storage devices.

Table of Contents

PROVIDING FEEDBACK ON RED HAT DOCUMENTATION 7

CHAPTER 1. OVERVIEW OF AVAILABLE STORAGE OPTIONS 8
1.1. LOCAL STORAGE OVERVIEW 8
1.2. REMOTE STORAGE OVERVIEW 9
1.3. GFS2 FILE SYSTEM OVERVIEW 10

CHAPTER 2. PERSISTENT NAMING ATTRIBUTES 12
2.1. PERSISTENT ATTRIBUTES FOR IDENTIFYING FILE SYSTEMS AND BLOCK DEVICES 13
2.2. UDEV DEVICE NAMING RULES 14
2.2.1. Obtaining the device links value for an existing device 17

CHAPTER 3. DISK PARTITIONS 19
3.1. OVERVIEW OF PARTITIONS 19
3.2. COMPARISON OF PARTITION TABLE TYPES 19
3.3. MBR DISK PARTITIONS 19
3.4. EXTENDED MBR PARTITIONS 21
3.5. MBR PARTITION TYPES 21
3.6. GUID PARTITION TABLE 23
3.7. PARTITION TYPES 24
3.8. PARTITION NAMING SCHEME 25
3.9. MOUNT POINTS AND DISK PARTITIONS 26

CHAPTER 4. GETTING STARTED WITH PARTITIONS 27
4.1. CREATING A PARTITION TABLE ON A DISK WITH PARTED 27
4.2. VIEWING THE PARTITION TABLE WITH PARTED 28
4.3. CREATING A PARTITION WITH PARTED 29
4.4. SETTING A PARTITION TYPE WITH FDISK 31
4.5. RESIZING A PARTITION WITH PARTED 31
4.6. REMOVING A PARTITION WITH PARTED 33

CHAPTER 5. STRATEGIES FOR REPARTITIONING A DISK 35
5.1. USING UNPARTITIONED FREE SPACE 35
5.2. USING SPACE FROM AN UNUSED PARTITION 35
5.3. USING FREE SPACE FROM AN ACTIVE PARTITION 36
5.3.1. Destructive repartitioning 36
5.3.2. Non-destructive repartitioning 37

CHAPTER 6. CONFIGURING AN ISCSI TARGET 40
6.1. INSTALLING TARGETCLI 40
6.2. CREATING AN ISCSI TARGET 41
6.3. ISCSI BACKSTORE 42
6.4. CREATING A FILEIO STORAGE OBJECT 42
6.5. CREATING A BLOCK STORAGE OBJECT 43
6.6. CREATING A PSCSI STORAGE OBJECT 43
6.7. CREATING A MEMORY COPY RAM DISK STORAGE OBJECT 44
6.8. CREATING AN ISCSI PORTAL 45
6.9. CREATING AN ISCSI LUN 46
6.10. CREATING A READ-ONLY ISCSI LUN 47
6.11. CREATING AN ISCSI ACL 48
6.12. SETTING UP THE CHALLENGE-HANDSHAKE AUTHENTICATION PROTOCOL FOR THE TARGET 49
6.13. REMOVING AN ISCSI OBJECT USING TARGETCLI TOOL 50

CHAPTER 7. CONFIGURING AN ISCSI INITIATOR 52
7.1. CREATING AN ISCSI INITIATOR 52
7.2. SETTING UP THE CHALLENGE-HANDSHAKE AUTHENTICATION PROTOCOL FOR THE INITIATOR 53
7.3. MONITORING AN ISCSI SESSION BY USING THE ISCSIADM UTILITY 54
7.4. DM MULTIPATH OVERRIDES OF THE DEVICE TIMEOUT 55

CHAPTER 8. USING FIBRE CHANNEL DEVICES 56
8.1. RE-SCANNING FIBRE CHANNEL LOGICAL UNITS AFTER RESIZING A LUN 56
8.2. DETERMINING THE LINK LOSS BEHAVIOR OF DEVICE USING FIBRE CHANNEL 56
8.3. FIBRE CHANNEL CONFIGURATION FILES 57

CHAPTER 9. OVERVIEW OF NVME OVER FABRIC DEVICES 59

CHAPTER 10. CONFIGURING NVME OVER FABRICS USING NVME/RDMA 60
10.1. SETTING UP AN NVME/RDMA CONTROLLER USING CONFIGFS 60
10.2. SETTING UP THE NVME/RDMA CONTROLLER USING NVMETCLI 61
10.3. CONFIGURING AN NVME/RDMA HOST 62
10.4. NEXT STEPS 64

CHAPTER 11. CONFIGURING NVME OVER FABRICS USING NVME/FC 65
11.1. CONFIGURING THE NVME HOST FOR BROADCOM ADAPTERS 65
11.2. CONFIGURING THE NVME HOST FOR QLOGIC ADAPTERS 67
11.3. NEXT STEPS 68

CHAPTER 12. CONFIGURING NVME OVER FABRICS USING NVME/TCP 69
12.1. CONFIGURING AN NVME/TCP HOST 69
12.2. CONNECTING THE NVME/TCP HOST TO THE NVME/TCP CONTROLLER 70
12.3. CONFIGURING NVME HOST AUTHENTICATION 72
12.4. CONFIGURING AN NVME/TCP HOST USING TLS WITH PRE-SHARED-KEYS 73
12.5. ADDITIONAL RESOURCES 75

CHAPTER 13. ENABLING MULTIPATHING ON NVME DEVICES 76
13.1. NATIVE NVME MULTIPATHING AND DM MULTIPATH 76
13.2. ENABLING DM MULTIPATH ON NVME DEVICES 76
13.3. ENABLING NATIVE NVME MULTIPATHING 78

CHAPTER 14. SETTING UP A REMOTE DISKLESS SYSTEM 81
14.1. PREPARING ENVIRONMENTS FOR THE REMOTE DISKLESS SYSTEM 81
14.2. CONFIGURING A TFTP SERVICE FOR DISKLESS CLIENTS 82
14.3. CONFIGURING A DHCP SERVER FOR DISKLESS CLIENTS 83
14.4. CONFIGURING AN EXPORTED FILE SYSTEM FOR DISKLESS CLIENTS 84
14.5. RE-CONFIGURING A REMOTE DISKLESS SYSTEM 86
14.6. TROUBLESHOOTING COMMON ISSUES WITH LOADING A REMOTE DISKLESS SYSTEM 87

CHAPTER 15. GETTING STARTED WITH SWAP 89
15.1. OVERVIEW OF SWAP SPACE 89
15.2. RECOMMENDED SYSTEM SWAP SPACE 89
15.3. CREATING AN LVM2 LOGICAL VOLUME FOR SWAP 90
15.4. CREATING AND MANAGING A STANDARD SWAP PARTITION 91
15.5. CREATING A SWAP FILE 92
15.6. CREATING A SWAP VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE 93
15.7. EXTENDING SWAP ON AN LVM2 LOGICAL VOLUME 94
15.8. REDUCING SWAP ON AN LVM2 LOGICAL VOLUME 94
15.9. REMOVING AN LVM2 LOGICAL VOLUME FOR SWAP 95
15.10. REMOVING A SWAP FILE 96

15.11. ADJUSTING VIRTUAL MEMORY (VM) TUNABLES 96

CHAPTER 16. CONFIGURING FIBRE CHANNEL OVER ETHERNET **98**
16.1. USING HARDWARE FCOE HBAS IN RHEL 98
16.2. SETTING UP AN FCOE DEVICE 98

CHAPTER 17. MANAGING TAPE DEVICES **101**
17.1. TYPES OF TAPE DEVICES 101
17.2. INSTALLING TAPE DRIVE MANAGEMENT TOOL 101
17.3. TAPE COMMANDS 101
17.4. WRITING TO REWINDING TAPE DEVICES 102
17.5. WRITING TO NON-REWINDING TAPE DEVICES 103
17.6. SWITCHING TAPE HEAD IN TAPE DEVICES 104
17.7. RESTORING DATA FROM TAPE DEVICES 105
17.8. ERASING DATA FROM TAPE DEVICES 106

CHAPTER 18. MANAGING RAID **107**
18.1. OVERVIEW OF RAID 107
18.2. RAID TYPES 107
18.3. RAID LEVELS AND LINEAR SUPPORT 109
18.4. SUPPORTED RAID CONVERSIONS 110
18.5. RAID SUBSYSTEMS 112
18.6. CREATING A SOFTWARE RAID DURING THE INSTALLATION 113
18.7. CREATING A SOFTWARE RAID ON AN INSTALLED SYSTEM 114
18.8. CREATING RAID IN THE WEB CONSOLE 115
18.9. FORMATTING RAID IN THE WEB CONSOLE 116
18.10. CREATING A PARTITION TABLE ON RAID BY USING THE WEB CONSOLE 117
18.11. CREATING PARTITIONS ON RAID BY USING THE WEB CONSOLE 118
18.12. CREATING A VOLUME GROUP ON TOP OF RAID BY USING THE WEB CONSOLE 119
18.13. CONFIGURING A RAID VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE 120
18.14. EXTENDING RAID 121
18.15. SHRINKING RAID 121
18.16. CONVERTING A ROOT DISK TO RAID1 AFTER INSTALLATION 122
18.17. CREATING ADVANCED RAID DEVICES 122
18.18. SETTING UP EMAIL NOTIFICATIONS TO MONITOR A RAID 123
18.19. REPLACING A FAILED DISK IN RAID 124
18.20. REPAIRING RAID DISKS 125

CHAPTER 19. ENCRYPTING BLOCK DEVICES USING LUKS **127**
19.1. LUKS DISK ENCRYPTION 127
19.2. LUKS VERSIONS IN RHEL 128
19.3. OPTIONS FOR DATA PROTECTION DURING LUKS2 RE-ENCRYPTION 129
19.4. ENCRYPTING EXISTING DATA ON A BLOCK DEVICE USING LUKS2 129
19.5. ENCRYPTING EXISTING DATA ON A BLOCK DEVICE USING LUKS2 WITH A DETACHED HEADER 132
19.6. ENCRYPTING A BLANK BLOCK DEVICE USING LUKS2 134
19.7. CONFIGURING THE LUKS PASSPHRASE IN THE WEB CONSOLE 136
19.8. CHANGING THE LUKS PASSPHRASE IN THE WEB CONSOLE 137
19.9. CHANGING THE LUKS PASSPHRASE BY USING THE COMMAND LINE 137
19.10. CREATING A LUKS2 ENCRYPTED VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE 138

CHAPTER 20. USING NVDIMM PERSISTENT MEMORY STORAGE **141**
20.1. THE NVDIMM PERSISTENT MEMORY TECHNOLOGY 141
20.2. NVDIMM INTERLEAVING AND REGIONS 141
20.3. NVDIMM NAMESPACES 142

20.4. NVDIMM ACCESS MODES 142
20.5. INSTALLING NDCTL 143
20.6. CREATING A SECTOR NAMESPACE ON AN NVDIMM TO ACT AS A BLOCK DEVICE 143
20.6.1. Reconfiguring an existing NVDIMM namespace to sector mode 143
20.6.2. Creating a new NVDIMM namespace in sector mode 145
20.7. CREATING A DEVICE DAX NAMESPACE ON AN NVDIMM 147
20.7.1. NVDIMM in device direct access mode 147
20.7.2. Reconfiguring an existing NVDIMM namespace to device DAX mode 148
20.7.3. Creating a new NVDIMM namespace in device DAX mode 149
20.8. CREATING A FILE SYSTEM DAX NAMESPACE ON AN NVDIMM 152
20.8.1. NVDIMM in file system direct access mode 152
20.8.2. Reconfiguring an existing NVDIMM namespace to file system DAX mode 153
20.8.3. Creating a new NVDIMM namespace in file system DAX mode 155
20.8.4. Creating a file system on a file system DAX device 157
20.9. MONITORING NVDIMM HEALTH USING S.M.A.R.T. 158
20.10. DETECTING AND REPLACING A BROKEN NVDIMM DEVICE 159

CHAPTER 21. DISCARDING UNUSED BLOCKS **162**
Requirements 162
21.1. TYPES OF BLOCK DISCARD OPERATIONS 162
Recommendations 162
21.2. PERFORMING BATCH BLOCK DISCARD 162
21.3. ENABLING ONLINE BLOCK DISCARD 163
21.4. ENABLING ONLINE BLOCK DISCARD BY USING THE STORAGE RHEL SYSTEM ROLE 163
21.5. ENABLING PERIODIC BLOCK DISCARD 164

CHAPTER 22. REMOVING STORAGE DEVICES **166**
22.1. SAFE REMOVAL OF STORAGE DEVICES 166
22.2. REMOVING BLOCK DEVICES AND ASSOCIATED METADATA 166

CHAPTER 23. SETTING UP STRATIS FILE SYSTEMS **170**
23.1. COMPONENTS OF A STRATIS FILE SYSTEM 170
23.2. BLOCK DEVICES COMPATIBLE WITH STRATIS 171
Supported devices 171
23.3. INSTALLING STRATIS 171
23.4. CREATING AN UNENCRYPTED STRATIS POOL 172
23.5. CREATING AN UNENCRYPTED STRATIS POOL BY USING THE WEB CONSOLE 173
23.6. CREATING AN ENCRYPTED STRATIS POOL USING A KEY IN THE KERNEL KEYRING 173
23.7. CREATING AN ENCRYPTED STRATIS POOL USING CLEVIS 175
23.8. CREATING AN ENCRYPTED STRATIS POOL BY USING THE STORAGE RHEL SYSTEM ROLE 176
23.9. CREATING AN ENCRYPTED STRATIS POOL BY USING THE WEB CONSOLE 178
23.10. RENAMING A STRATIS POOL BY USING THE WEB CONSOLE 179
23.11. SETTING OVERPROVISIONING MODE IN STRATIS FILE SYSTEM 180
23.12. BINDING A STRATIS POOL TO NBDE 181
23.13. BINDING A STRATIS POOL TO TPM 182
23.14. UNLOCKING AN ENCRYPTED STRATIS POOL WITH KERNEL KEYRING 182
23.15. UNBINDING A STRATIS POOL FROM SUPPLEMENTARY ENCRYPTION 183
23.16. STARTING AND STOPPING STRATIS POOL 183
23.17. CREATING A STRATIS FILE SYSTEM 184
23.18. CREATING A FILE SYSTEM ON A STRATIS POOL BY USING THE WEB CONSOLE 185
23.19. MOUNTING A STRATIS FILE SYSTEM 186
23.20. SETTING UP NON-ROOT STRATIS FILE SYSTEMS IN /ETC/FSTAB USING A SYSTEMD SERVICE 187

CHAPTER 24. EXTENDING A STRATIS POOL WITH ADDITIONAL BLOCK DEVICES **188**

24.1. ADDING BLOCK DEVICES TO A STRATIS POOL 188
24.2. ADDING A BLOCK DEVICE TO A STRATIS POOL BY USING THE WEB CONSOLE 188

CHAPTER 25. MONITORING STRATIS FILE SYSTEMS 190
25.1. DISPLAYING INFORMATION ABOUT STRATIS FILE SYSTEMS 190
25.2. VIEWING A STRATIS POOL BY USING THE WEB CONSOLE 191

CHAPTER 26. USING SNAPSHOTS ON STRATIS FILE SYSTEMS 192
26.1. CHARACTERISTICS OF STRATIS SNAPSHOTS 192
26.2. CREATING A STRATIS SNAPSHOT 192
26.3. ACCESSING THE CONTENT OF A STRATIS SNAPSHOT 192
26.4. REVERTING A STRATIS FILE SYSTEM TO A PREVIOUS SNAPSHOT 193
26.5. REMOVING A STRATIS SNAPSHOT 195

CHAPTER 27. REMOVING STRATIS FILE SYSTEMS 196
27.1. REMOVING A STRATIS FILE SYSTEM 196
27.2. DELETING A FILE SYSTEM FROM A STRATIS POOL BY USING THE WEB CONSOLE 196
27.3. REMOVING A STRATIS POOL 197
27.4. DELETING A STRATIS POOL BY USING THE WEB CONSOLE 198

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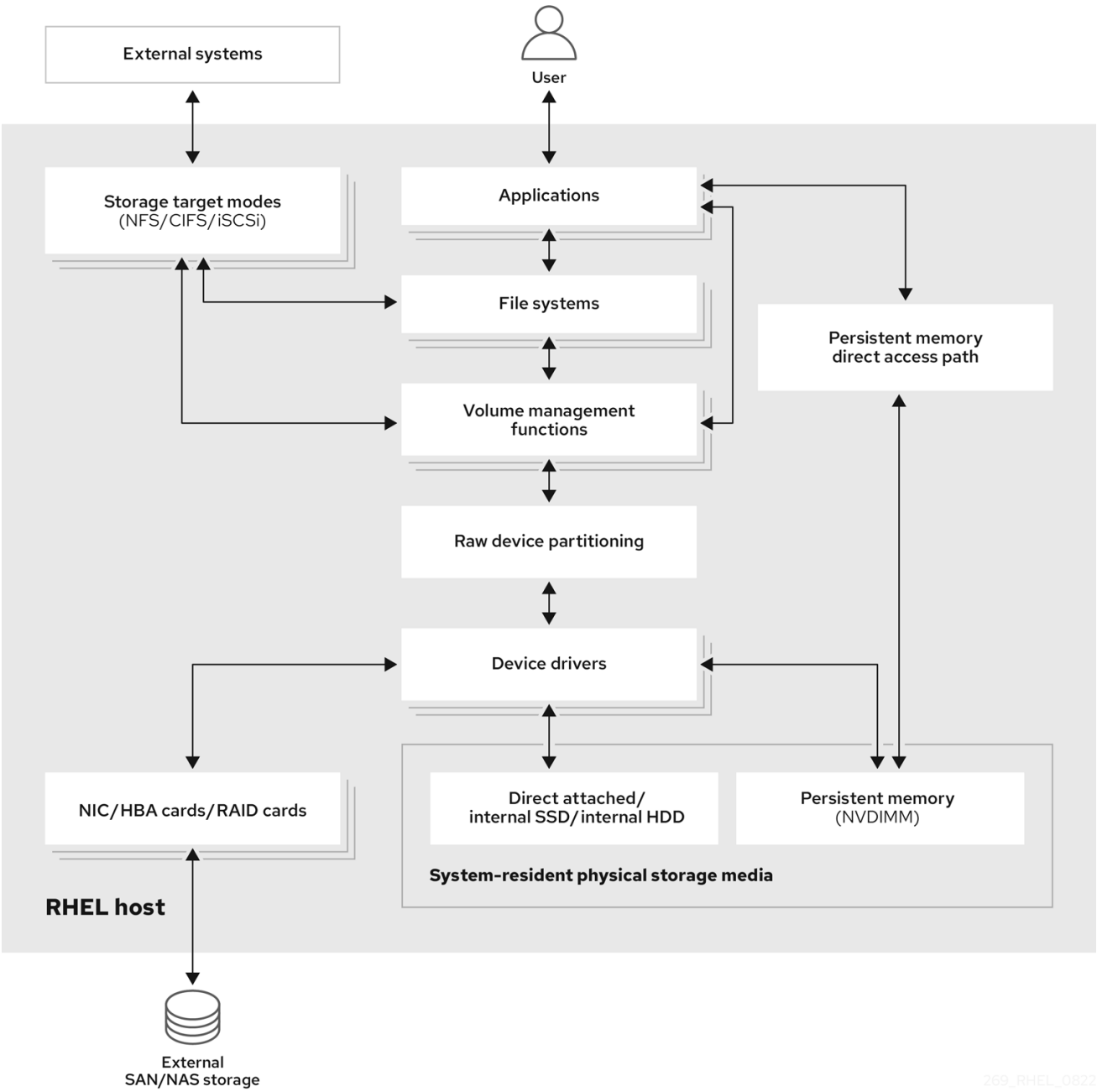
CHAPTER 1. OVERVIEW OF AVAILABLE STORAGE OPTIONS

There are several local, remote, and cluster-based storage options available on RHEL 9.

Local storage implies that the storage devices are either installed on the system or directly attached to the system.

With remote storage, devices are accessed over LAN, the internet, or using a Fibre channel network. The following high level Red Hat Enterprise Linux storage diagram describes the different storage options.

Figure 1.1. High level Red Hat Enterprise Linux storage diagram



1.1. LOCAL STORAGE OVERVIEW

Red Hat Enterprise Linux 9 offers several local storage options.

Basic disk administration

Using **parted** and **fdisk**, you can create, modify, delete, and view disk partitions. The following are the partitioning layout standards:

Master Boot Record (MBR)

It is used with BIOS-based computers. You can create primary, extended, and logical partitions.

GUID Partition Table (GPT)

It uses globally unique identifier (GUID) and provides unique disk and partition GUID.

Storage consumption options

Non-Volatile Dual In-line Memory Modules (NVDIMM) Management

It is a combination of memory and storage. You can enable and manage various types of storage on NVDIMM devices connected to your system.

Block Storage Management

Data is stored in the form of blocks where each block has a unique identifier.

File Storage

Data is stored at file level on the local system. These data can be accessed locally using XFS (default) or ext4, and over a network by using NFS and SMB.

Logical volumes

Logical Volume Manager (LVM)

It creates logical devices from physical devices. Logical volume (LV) is a combination of the physical volumes (PV) and volume groups (VG).

Virtual Data Optimizer (VDO)

It is used for data reduction by using deduplication, compression, and thin provisioning. Using LV below VDO helps in:

- Extending of VDO volume
- Spanning VDO volume over multiple devices

Local file systems

XFS

The default RHEL file system.

Ext4

A legacy file system.

Stratis

Stratis is a hybrid user-and-kernel local storage management system that supports advanced storage features.

1.2. REMOTE STORAGE OVERVIEW

The following are the remote storage options available in RHEL 9:

Storage connectivity options

iSCSI

RHEL 9 uses the targetcli tool to add, remove, view, and monitor iSCSI storage interconnects.

Fibre Channel (FC)

RHEL 9 provides the following native Fibre Channel drivers:

- **lpfc**
- **qla2xxx**
- **Zfcp**

Non-volatile Memory Express (NVMe)

An interface which allows host software utility to communicate with solid state drives. Use the following types of fabric transport to configure NVMe over fabrics:

- NVMe over fabrics using Remote Direct Memory Access (NVMe/RDMA)
- NVMe over fabrics using Fibre Channel (NVMe/FC)
- NVMe over fabrics using TCP (NVMe/TCP)

Device Mapper multipathing (DM Multipath)

Allows you to configure multiple I/O paths between server nodes and storage arrays into a single device. These I/O paths are physical SAN connections that can include separate cables, switches, and controllers.

Network file system

- NFS
- SMB

1.3. GFS2 FILE SYSTEM OVERVIEW

The Red Hat Global File System 2 (GFS2) file system is a 64-bit symmetric cluster file system which provides a shared name space and manages coherency between multiple nodes sharing a common block device. A GFS2 file system is intended to provide a feature set which is as close as possible to a local file system, while at the same time enforcing full cluster coherency between nodes. To achieve this, the nodes employ a cluster-wide locking scheme for file system resources. This locking scheme uses communication protocols such as TCP/IP to exchange locking information.

In a few cases, the Linux file system API does not allow the clustered nature of GFS2 to be totally transparent; for example, programs using POSIX locks in GFS2 should avoid using the **GETLK** function since, in a clustered environment, the process ID may be for a different node in the cluster. In most cases however, the functionality of a GFS2 file system is identical to that of a local file system.

The Red Hat Enterprise Linux Resilient Storage Add-On provides GFS2, and it depends on the Red Hat Enterprise Linux High Availability Add-On to provide the cluster management required by GFS2.

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

To get the best performance from GFS2, it is important to take into account the performance considerations which stem from the underlying design. Just like a local file system, GFS2 relies on the page cache in order to improve performance by local caching of frequently used data. In order to

maintain coherency across the nodes in the cluster, cache control is provided by the *glock* state machine.

Additional resources

- Configuring GFS2 file systems

CHAPTER 2. PERSISTENT NAMING ATTRIBUTES

The way you identify and manage storage devices ensures the stability and predictability of the system. RHEL 9 uses two primary naming schemes for this purpose: traditional device names and persistent naming attributes.

Traditional device names

The Linux kernel assigns traditional device names based on the order in which they appear in the system or their enumeration. For example, the first SATA drive is usually labeled as **/dev/sda**, the second as **/dev/sdb**, and so on. While these names are straightforward, they are subject to change when devices are added or removed, the hardware configuration is modified, or the system is rebooted. This can pose challenges for scripting and configuration files. Furthermore, traditional names lack descriptive information about the purpose or characteristics of the device.

Persistent naming attributes

Persistent naming attributes (PNAs) are based on unique characteristics of the storage devices, making them more stable and predictable when presented to the system, even across system reboots. One of the key benefits of PNAs is their resilience to changes in hardware configurations, making them ideal for maintaining consistent naming conventions. When using PNAs, you can reference storage devices within scripts, configuration files, and management tools without concerns about unexpected name changes. Additionally, PNAs often include valuable metadata, such as device type or manufacturer information like combination of vendor, model name, and serial number, enhancing their descriptiveness for effective device identification and management. PNAs are eventually used to create device links in **/dev/disk** directory to access individual devices. The way the device link names are constructed and managed is driven by **udev** rules.

The following is a list of directories we can find in **/dev/disk/**:

- Directories with content that remain unique even after system restart:
  - **by-id**: based on hardware attributes, with the **vendor/model/serial_string** combination.
  - **by-path***: Based on physical hardware placement. For devices or disks physically attached to a machine, this is the slot or port where they are connected physically to the host bus on the motherboard. However, for devices or disks attached over a network, this contains the network address specification.
  - **by-partlabel**: Based on a label assigned to a device partition. These labels are assigned by the user.
  - **by-partuuid**: Based on a unique number in the form of **UUID** that is auto-generated.
  - **by-uuid**: Based on a unique number in the form of UUID that is autogenerated.
- Directory with content that remain unique during the current system run, but not after system restart:
  - **by-diskseq**: **diskseq`** is 'disk sequence number' that starts at 1 when the system boots. It assigns this number to a newly attached disk and each one after that gets the next number in sequence. When the system reboots, the counter restarts at 1.
- Directories with content that are used specifically for loop devices:
  - **by-loop-ref**

- **by-loop-inode**

2.1. PERSISTENT ATTRIBUTES FOR IDENTIFYING FILE SYSTEMS AND BLOCK DEVICES

In RHEL 9 storage, persistent naming attributes (PNAs) are mechanisms that provide components for consistent and reliable naming for storage devices across system reboots, hardware changes, or other events. These attributes are used to identify storage devices consistently, even if the storage devices are added, removed, or reconfigured.

PNAs are used to identify both file systems and block devices, but they serve different purposes:

Persistent attributes for identifying file systems

- Universally unique identifier (UUID)
  UUIDs are primarily used to uniquely identify file systems on storage devices. Each file system instance has its own UUID assigned automatically, and this identifier remains constant even if the file system is unmounted, remounted, or the device is detached and reattached.

- Label
  Labels are user-assigned names for file systems. While they can be used to identify and reference file systems, they are not as standardized as UUIDs. Since a user assigns the file system label, its uniqueness depends on their choice. Labels are often used as alternatives to UUIDs to specify file systems in configuration files.

  When you assign a label to a file system, it becomes part of the file system metadata. This label remains associated with the file system even if it is unmounted, remounted, or the device is detached and reattached.

Persistent attributes for identifying block devices

- Universally unique identifier (UUID)
  UUIDs can be used to identify storage block devices. When a storage device is formatted, a UUID is often assigned to the device itself. Such UUIDs are usually generated and assigned to virtual block devices layered on top of other block devices, where the real devices are at the bottom level. For example, device-mapper (DM) based devices and their related subsystems, such as Logical Volume Manager (LVM) and crypt, use UUIDs for device identification, such as Logical Volume UUID (LVUUID) and crypt UUID.

  Also, multiple-device (MD) based devices have UUIDs assigned. The virtual devices usually also mark the underlying devices with component UUIDs. For example, LVM marks its underlying devices with a Physical Volume UUID (PVUUID) and MD marks its underlying devices with an MD component UUID.

  These UUIDs are embedded within the virtual block device metadata and they are used as persistent naming attributes. It allows you to uniquely identify the block device, even if you change the file system that resides on it. UUIDs are also assigned for device partitions.

  Such UUIDs can coexist with other device IDs. For example, an sda device at the bottom of the device stack which is identified by its **vendor/model/serial_number** combination or WWID, can also have a PVUUID assigned by LVM. This is then recognized by LVM itself to build up the Volume Group (VG) or Logical Volume (LV) in a layer above it.

- Label or Name Labels or names can be assigned to certain block devices too. This applies to partitions which can have user-assigned labels. Some of the virtual block devices, like

device-mapper (DM) based devices and multiple-device (MD) based devices also use names to identify devices.

- World Wide Identifier (WWID)
  WWID encompasses a family of identifiers which are globally unique and they are associated with storage block devices or storage components in general. They are commonly used in enterprise-level Storage Area Networks (SANs), like Fibre Channel (FC), to identify a storage node - World Wide Node Name (WWNN) or actual port/connection to a storage device on the node - World Wide Port Name (WWPN). WWIDs ensure consistent communication between servers and SAN storage devices and help manage redundant paths to storage devices.

  Other types of devices may use a form of WWIDs too, like NVME devices. These devices do not necessarily need to be accessed over a network or SAN, and they do not have to be enterprise-level devices either.

  The WWID format does not follow a single standard. For example, SCSI uses formats such as NAA, T10, and EUI. The NVME uses formats such as EUI-64, NGUUID, and UUID.

- Serial string
  The serial string is a unique string identifier assigned to each storage block device by the manufacturer. It can be used to differentiate among storage devices and may be used in combination with other attributes like UUIDs or WWIDs for device management.

  Within **udev rules**, and consequently in the **/dev/disk/by-id** content, the 'short serial string' typically represents the actual serial string as reported by the device itself. Whereas, 'serial string' is composed of several components, usually **<bus_type>-<vendor_name>_<model_name>_<short_serial_string>**.

  WWIDs and serial strings are preferred for real devices. For virtual devices, UUIDs or names is preferred.

2.2. UDEV DEVICE NAMING RULES

Userspace device manager (**udev**) subsystem allows you to define rules for assigning persistent names to devices. These rules are stored in a file with a **.rules** extension. There are two primary locations for storing the udev rules:

- **/usr/lib/udev/rules.d/** directory contains default rules that come with an installed package.
- **/etc/udev/rules.d** directory is intended for custom **udev** rules.

NOTE

If a rule from **/usr/lib/udev/rules.d/** is modified, it will be overwritten by the rules file of the package during an update. Hence, any manual or custom rule should be added in **/etc/udev/rules.d** where it is retained until removed explicitly. Before use, **udev** rules from both directories are merged. If a rule in **/etc/udev/rules.d** has the same name as one in **/usr/lib/udev/rules.d/** the one in the former takes precedence.

The purpose of these rules is to ensure that storage devices are consistently and predictably identified, even across system reboots and configuration changes.

udev rules define actions to execute based on incoming events that notify about adding, changing or removing a device. This also helps to collect values for the persistent storage attributes and direct **udev** to create the **/dev** content based on the collected information. The **udev** rules are written in human-readable format using key-value pairs.

In the case of storage devices, **udev** rules control creation of symbolic links in the **/dev/disk/** directory. These symbolic links provide user-friendly aliases for storage devices, making it more convenient to refer to and manage these devices.

You can create custom **udev** rules to specify how devices should be named based on various attributes such as serial numbers, World Wide Name (WWN) identifiers, or other device-specific characteristics. By defining specific naming rules, you have precise control over how devices are identified within the system. To create a specific custom symbolic link in /dev for a device see the **udev(7)** man page on your system.

While **udev** rules are very flexible, it is important to be aware of **udev** limitations:

- Accessibility Timing: Some storage devices might not be accessible at the time of a **udev** query.
- Event-Based Processing: The kernel can send **udev** events at any time, potentially triggering rule processing and link removal if a device is inaccessible.
- Processing Delay: There might be a delay between event generation and processing, especially with numerous devices, causing a lag between kernel detection and link availability.
- Device Accessibility: External programs invoked by **udev** rules, like **blkid**, might briefly open the device, making it temporarily inaccessible for other tasks.
- Link Updates: Device names managed by **udev** in **/dev/disk/** can change between major releases, requiring link updates.

The following table lists the symlinks available in /dev/disk.

Device type	Nonpersistent Name (Kernel Name)	Persistent Symlink Names
Real Devices		
nvme (Non-Volatile Memory Express)	/dev/nvme*	/dev/disk/by-id/nvme-<wwid> /dev/disk/by-id/nvme-<model>_<serial>_<nsid>

Device type	Nonpersistent Name (Kernel Name)	Persistent Symlink Names
scsi (Small Computer System Interface)	/dev/sd*, /dev/sr*	/dev/disk/by-id/scsi-<model>_<serial> /dev/disk/by-id/wwn-<wwn> /dev/disk/by-id/usb-<vendor>_<model>_<serial>-<instance> /dev/disk/by-id/ieee1394-<ieee1394_id> /dev/disk/by-path/ip-<ip_address>:<ip_port>-iscsi-<iqn_name>-lun-<lun_number> /dev/disk/by-id/scsi-0<vendor>_<model>_<id> /dev/disk/by-id/scsi-1<t10_vendor_id> /dev/disk/by-id/scsi-2<eui64_id> /dev/disk/by-id/scsi-3<naa_regext_id> /dev/disk/by-id/scsi-3<naa_reg_id> /dev/disk/by-id/scsi-3<naa_ext_id> /dev/disk/by-id/scsi-3<naa_local_id> /dev/disk/by-id/scsi-8<name> /dev/disk/by-id/scsi-S<vendor>_<model>_<serial>
ata (Advanced Technology Attachment)/atapi (ATA Packet Interface)	/dev/sd*, /dev/sr*	/dev/disk/by-id/ata-<model>_<serial> /dev/disk/by-id/wwn-<wwn>
cciss (Compaq Command Interface for SCSI-3 Support)	/dev/cciss*	/dev/disk/by-id/cciss-<model>_<serial> /dev/cciss/<ccissid>
virtio (Virtual Input Output)	/dev/vd*	/dev/disk/by-id/virtio-<serial>
pmem (Persistent Memory)	/dev/pmem*	/dev/disk/by-id/pmem-<uuid>
mmc (MultiMedia Card)	/dev/mmcblk*	/dev/disk/by-id/mmc-<name>_<serial>
memstick (Memory Stick)	/dev/msblk*	/dev/disk/by-id/memstick-<name>_<serial>
Virtual devices		

Device type	Nonpersistent Name (Kernel Name)	Persistent Symlink Names
loop	/dev/loop*	/dev/disk/by-loop-inode/<id_loop_backing_device>-<id_loop_backing_inode> /dev/disk/by-loop-ref/<id_loop_backing_filename>
dm (device-mapper)	/dev/dm-*	/dev/mapper/<name> /dev/disk/by-id/dm-name-<name> /dev/disk/by-id/dm-uuid-<uuid> /dev/disk/by-id/wwn-<wwn>
md (multiple device)	/dev/md*	/dev/md/<devname> /dev/disk/by-id/md-name-<name> /dev/disk/by-id/md-uuid-<uuid>
Partitions (either on top of a real or a virtual device)		
(any)	(any)	/dev/disk/by-partuuid/<uuid> /dev/disk/by-partlabel/<label> /dev/... /<persistent_symlink_name>-part<number>
LVM PVs (Logical Volume Manager Physical Volumes; either on top of a real or a virtual device)		
(any)	(any)	/dev/disk/by-id/lvm-pv-uuid-<pvuuid>

2.2.1. Obtaining the device links value for an existing device

You can obtain the value of the device links for an existing device from the current **udev** database.

Prerequisites

- The device is present and connected to the system.

Procedure

- List all the assigned device symbolic links (**DEVLINKS**) to the base kernel device node (**DEVNAME**) under **/dev** for an existing device:

```
# udevadm info --name /dev/nvme0n1 --query property --property DEVLINKS --value

/dev/disk/by-path/pci-0000:00:02.0-nvme-1 /dev/disk/by-diskseq/6
/dev/disk/by-id/nvme-QEMU_NVMe_Ctrl_nvme-1_1
/dev/disk/by-id/nvme-QEMU_NVMe_Ctrl_nvme-1
```

```
/dev/disk/by-id/nvme-QEMU_NVMe_Ctrl_nvme-1-ns-1
/dev/disk/by-id/nvme-nvme.8086-6e766d652d31-51454d55204e564d65204374726c-
00000001
```

Replace *nvme0n1* with your device name.

- You can also obtain the base kernel name that all the devlinks point to by using the following command:

```
# udevadm info --name /dev/nvme0n1 --query property --property DEVNAME --value
/dev/nvme0n1
```

The kernel name and any of its devlinks can be used interchangeably.

- You can use one of the devlinks to get the full list of devlinks by using the following command:

```
# udevadm info --name /dev/disk/by-id/nvme-nvme.8086-6e766d652d31-
51454d55204e564d65204374726c-00000001 --query property --property DEVLINKS --value

/dev/disk/by-id/nvme-QEMU_NVMe_Ctrl_nvme-1
/dev/disk/by-diskseq/6
/dev/disk/by-id/nvme-nvme.8086-6e766d652d31-51454d55204e564d65204374726c-
00000001
/dev/disk/by-id/nvme-QEMU_NVMe_Ctrl_nvme-1-ns-1
/dev/disk/by-id/nvme-QEMU_NVMe_Ctrl_nvme-1_1
/dev/disk/by-path/pci-0000:00:02.0-nvme-1
```

CHAPTER 3. DISK PARTITIONS

To divide a disk into one or more logical areas, use the disk partitioning utility. It enables separate management of each partition.

3.1. OVERVIEW OF PARTITIONS

The hard disk stores information about the location and size of each disk partition in the partition table. Using information from the partition table, the operating system treats each partition as a logical disk. Some of the advantages of disk partitioning include:

- Reduce the likelihood of administrative oversights of Physical Volumes
- Ensure sufficient backup
- Provide efficient disk management

Additional resources

- What are the advantages and disadvantages to using partitioning on LUNs, either directly or with LVM in between? (Red Hat Knowledgebase)

3.2. COMPARISON OF PARTITION TABLE TYPES

To enable partitions on a device, format a block device with different types of partition tables. The following table compares the properties of different types of partition tables that you can create on a block device.

NOTE

This section does not cover the DASD partition table, which is specific to the IBM Z architecture.

Table 3.1. Partition table types

Partition table	Maximum number of partitions	Maximum partition size
Master Boot Record (MBR)	4 primary, or 3 primary and 1 extended partition with 12 logical partitions	2 TiB if using 512 b sector drives 16 TiB if using 4 k sector drives
GUID Partition Table (GPT)	128	8 ZiB if using 512 b sector drives 64 ZiB if using 4 k sector drives

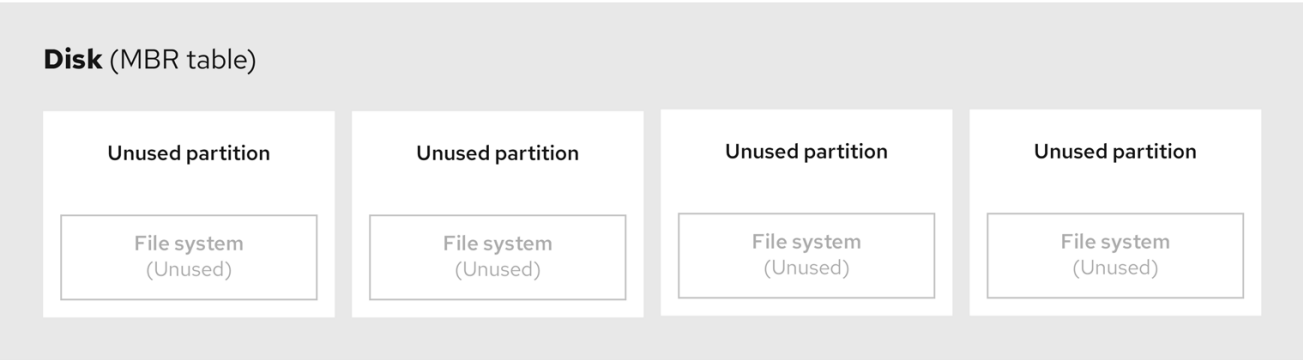
Additional resources

- Configuring a Linux instance on IBM Z
- What you should know about DASD

3.3. MBR DISK PARTITIONS

The partition table is stored at the very start of the disk, before any file system or user data. For a more clear example, the partition table is shown as being separate in the following diagrams.

Figure 3.1. Disk with MBR partition table



As the previous diagram shows, the partition table is divided into four sections of four unused primary partitions. A primary partition is a partition on a hard disk drive that contains only one logical drive (or section). Each logical drive holds the information necessary to define a single partition, meaning that the partition table can define no more than four primary partitions.

Each partition table entry contains important characteristics of the partition:

- The points on the disk where the partition starts and ends
- The state of the partition, as only one partition can be flagged as **active**
- The type of partition

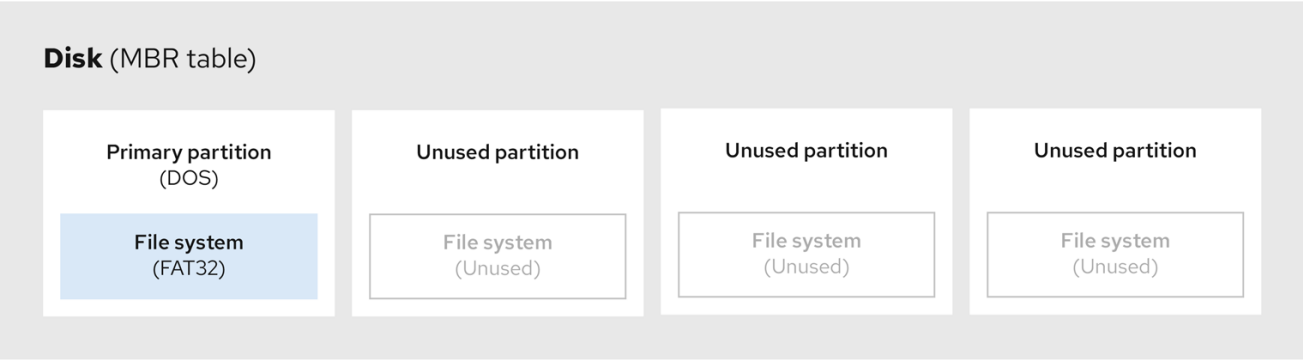
The starting and ending points define the size and location of the partition on the disk. Some of the operating systems boot loaders use the **active** flag. That means that the operating system in the partition that is marked "active" is booted.

The type is a number that identifies the anticipated usage of a partition. Some operating systems use the partition type to:

- Denote a specific file system type
- Flag the partition as being associated with a particular operating system
- Indicate that the partition contains a bootable operating system

The following diagram shows an example of a drive with a single partition. In this example, the first partition is labeled as **DOS** partition type:

Figure 3.2. Disk with a single partition



Additional resources

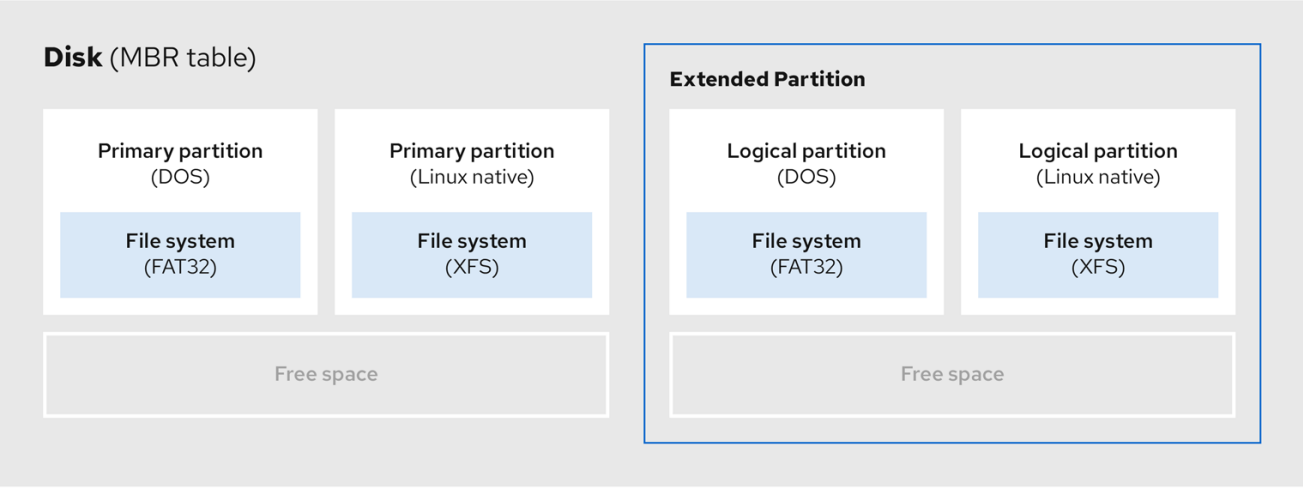
- MBR partition types

3.4. EXTENDED MBR PARTITIONS

To create additional partitions, if needed, set the type to **extended**.

An extended partition is similar to a disk drive. It has its own partition table, which points to one or more logical partitions, contained entirely within the extended partition. The following diagram shows a disk drive with two primary partitions, and one extended partition containing two logical partitions, along with some unpartitioned free space.

Figure 3.3. Disk with both two primary and an extended MBR partitions



You can have only up to four primary and extended partitions, but there is no fixed limit to the number of logical partitions. As a limit in Linux to access partitions, a single disk drive allows maximum 15 partitions.

3.5. MBR PARTITION TYPES

The table below shows a list of some of the most commonly used MBR partition types and hexadecimal numbers to represent them.

Table 3.2. MBR partition types

MBR partition type	Value	MBR partition type	Value
Empty	00	Novell Netware 386	65
DOS 12-bit FAT	01	PIC/IX	75
XENIX root	O2	Old MINIX	80
XENIX usr	O3	Linux/MINUX	81
DOS 16-bit ⇐32M	04	Linux swap	82
Extended	05	Linux native	83
DOS 16-bit >=32	06	Linux extended	85
OS/2 HPFS	07	Amoeba	93
AIX	08	Amoeba BBT	94
AIX bootable	09	BSD/386	a5
OS/2 Boot Manager	0a	OpenBSD	a6
Win95 FAT32	0b	NEXTSTEP	a7
Win95 FAT32 (LBA)	0c	BSDI fs	b7
Win95 FAT16 (LBA)	0e	BSDI swap	b8
Win95 Extended (LBA)	0f	Syrinx	c7
Venix 80286	40	CP/M	db
Novell	51	DOS access	e1
PRep Boot	41	DOS R/O	e3
GNU HURD	63	DOS secondary	f2
Novell Netware 286	64	BBT	ff

3.6. GUID PARTITION TABLE

The GUID partition table (GPT) is a partitioning scheme based on the Globally Unique Identifier (GUID).

GPT deals with the limitations of the Mater Boot Record (MBR) partition table. The MBR partition table cannot address storage larger than 2 TiB, equal to approximately 2.2 TB. Instead, GPT supports hard disks with larger capacity. The maximum addressable disk size is 8 ZiB, when using 512b sector drives, and 64 ZiB, when using 4096b sector drives. In addition, by default, GPT supports creation of up to 128 primary partitions. Extend the maximum amount of primary partitions by allocating more space to the partition table.

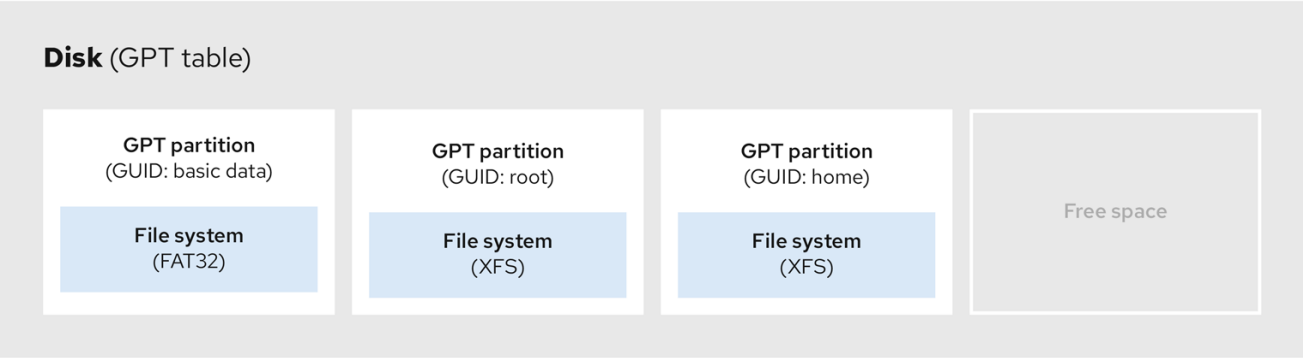
NOTE

A GPT has partition types based on GUIDs. Certain partitions require a specific GUID. For example, the system partition for Extensible Firmware Interface (EFI) boot loaders require GUID **C12A7328-F81F-11D2-BA4B-00A0C93EC93B**.

GPT disks use logical block addressing (LBA) and a partition layout as follows:

- For backward compatibility with MBR disks, the system reserves the first sector (LBA 0) of GPT for MBR data, and applies the name "protective MBR".
- Primary GPT
  - The header begins on the second logical block (LBA 1) of the device. The header contains the disk GUID, the location of the primary partition table, the location of the secondary GPT header, and CRC32 checksums of itself, and the primary partition table. It also specifies the number of partition entries on the table.
  - By default, the primary GPT includes 128 partition entries. Each partition has an entry size of 128 bytes, a partition type GUID and a unique partition GUID.
- Secondary GPT
  - For recovery, it is useful as a backup table in case the primary partition table is corrupted.
  - The last logical sector of the disk contains the secondary GPT header and recovers GPT information, in case the primary header is corrupted.
  - It contains:
    - The disk GUID
    - The location of the secondary partition table and the primary GPT header
    - CRC32 checksums of itself
    - The secondary partition table
    - The number of possible partition entries

Figure 3.4. Disk with a GUID Partition Table



269_RHEL_0822

IMPORTANT

For a successful installation of the boot loader onto a GPT disk a BIOS boot partition must be present. Reuse is possible only if the disk already contains a BIOS boot partition. This includes disks initialized by the **Anaconda** installation program.

3.7. PARTITION TYPES

There are multiple ways to manage partition types:

- The **fdisk** utility supports the full range of partition types by specifying hexadecimal codes.
- The **systemd-gpt-auto-generator**, a unit generator utility, uses the partition type to automatically identify and mount devices.
- The **parted** utility maps out the partition type with *flags*. The **parted** utility handles only certain partition types, for example LVM, swap or RAID.
  The **parted** utility supports setting the following flags:
  - **boot**
  - **root**
  - **swap**
  - **hidden**
  - **raid**
  - **lvm**
  - **lba**
  - **legacy_boot**
  - **irst**
  - **esp**
  - **palo**

On Red Hat Enterprise Linux 9 with **parted** 3.5, you can use the additional flags **chromeos_kernel** and **bls_boot**.

The **parted** utility optionally accepts a file system type argument while creating a partition. For a list of the required conditions, see Creating a partition with parted . Use the value to:

- Set the partition flags on MBR.
- Set the partition UUID type on GPT. For example, the **swap**, **fat**, or **hfs** file system types set different GUIDs. The default value is the Linux Data GUID.

The argument does not modify the file system on the partition. It only differentiates between the supported flags and GUIDs.

The following file system types are supported:

- **xfs**
- **ext2**
- **ext3**
- **ext4**
- **fat16**
- **fat32**
- **hfs**
- **hfs+**
- **linux-swap**
- **ntfs**
- **reiserfs**

3.8. PARTITION NAMING SCHEME

Red Hat Enterprise Linux uses a file-based naming scheme, with file names in the form of /**dev**/***xxyN***.

Device and partition names consist of the following structure:

/dev/

Name of the directory that contains all device files. Hard disks contain partitions, thus the files representing all possible partitions are located in /**dev**.

xx

The first two letters of the partition name indicate the type of device that contains the partition.

y

This letter indicates the specific device containing the partition. For example, /**dev**/**sda** for the first hard disk and /**dev**/**sdb** for the second. You can use more letters in systems with more than 26 drives, for example, /**dev**/**sdaa1**.

N

The final letter indicates the number to represent the partition. The first four (primary or extended) partitions are numbered **1** through **4**. Logical partitions start at **5**. For example, **/dev/sda3** is the third primary or extended partition on the first hard disk, and **/dev/sdb6** is the second logical partition on the second hard disk. Drive partition numbering applies only to MBR partition tables. Note that ***N*** does not always mean partition.

NOTE

Even if Red Hat Enterprise Linux can identify and refer to *all* types of disk partitions, it might not be able to read the file system and therefore access stored data on every partition type. However, in many cases, it is possible to successfully access data on a partition dedicated to another operating system.

3.9. MOUNT POINTS AND DISK PARTITIONS

In Red Hat Enterprise Linux, each partition forms a part of the storage, necessary to support a single set of files and directories. Mounting a partition makes the storage of that partition available, starting at the specified directory known as a *mount point*.

For example, if partition **/dev/sda5** is mounted on **/usr/**, it means that all files and directories under **/usr/** physically reside on **/dev/sda5**. The file **/usr/share/doc/FAQ/txt/Linux-FAQ** resides on **/dev/sda5**, while the file **/etc/gdm/custom.conf** does not.

Continuing the example, it is also possible that one or more directories below **/usr/** would be mount points for other partitions. For example, **/usr/local/man/whatis** resides on **/dev/sda7**, rather than on **/dev/sda5**, if **/usr/local** includes a mounted **/dev/sda7** partition.

CHAPTER 4. GETTING STARTED WITH PARTITIONS

Use disk partitioning to divide a disk into one or more logical areas which enables work on each partition separately. The hard disk stores information about the location and size of each disk partition in the partition table. Using the table, each partition then appears as a logical disk to the operating system. You can then read and write on those individual disks.

For an overview of the advantages and disadvantages to using partitions on block devices, see the Red Hat Knowledgebase solution What are the advantages and disadvantages to using partitioning on LUNs, either directly or with LVM in between?.

4.1. 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 4.1. 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

4.2. 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

4.3. 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 4.2. 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

4.4. SETTING A PARTITION TYPE WITH FDISK

You can set a partition type or flag, using the **fdisk** utility.

Prerequisites

- A partition on the disk.

Procedure

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

```
# fdisk block-device
```

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

```
Command (m for help): print
```

You can see the current partition type in the **Type** column and its corresponding type ID in the **Id** column.

3. Enter the partition type command and select a partition using its minor number:

```
Command (m for help): type
Partition number (1,2,3 default 3): 2
```

4. Optional: View the list in hexadecimal codes:

```
Hex code (type L to list all codes): L
```

5. Set the partition type:

```
Hex code (type L to list all codes): 8e
```

6. Write your changes and exit the **fdisk** shell:

```
Command (m for help): write
The partition table has been altered.
Syncing disks.
```

7. Verify your changes:

```
# fdisk --list block-device
```

4.5. 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

4.6. 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

CHAPTER 5. 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.

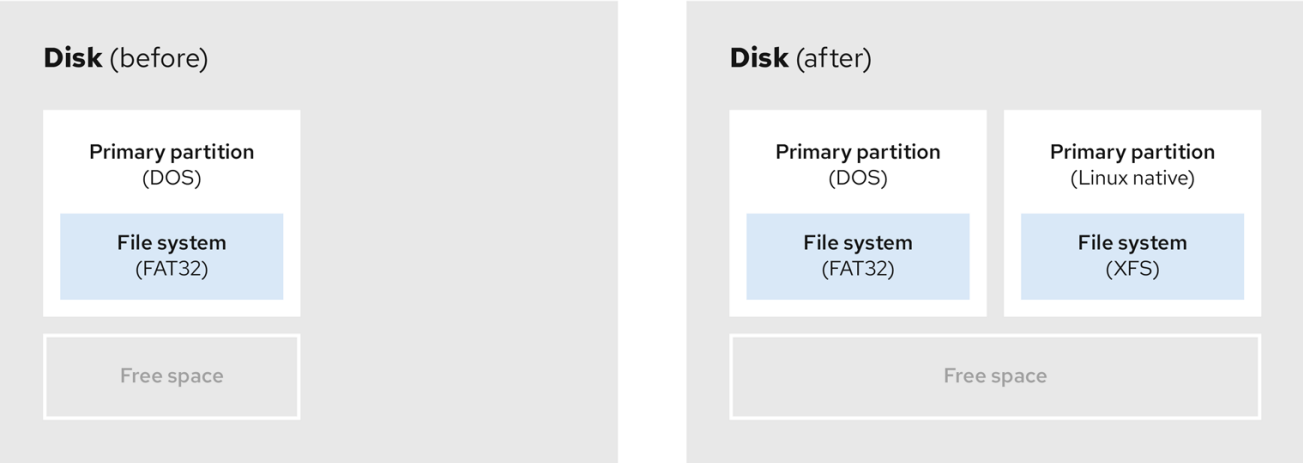
NOTE

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

5.1. 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 5.1. 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.

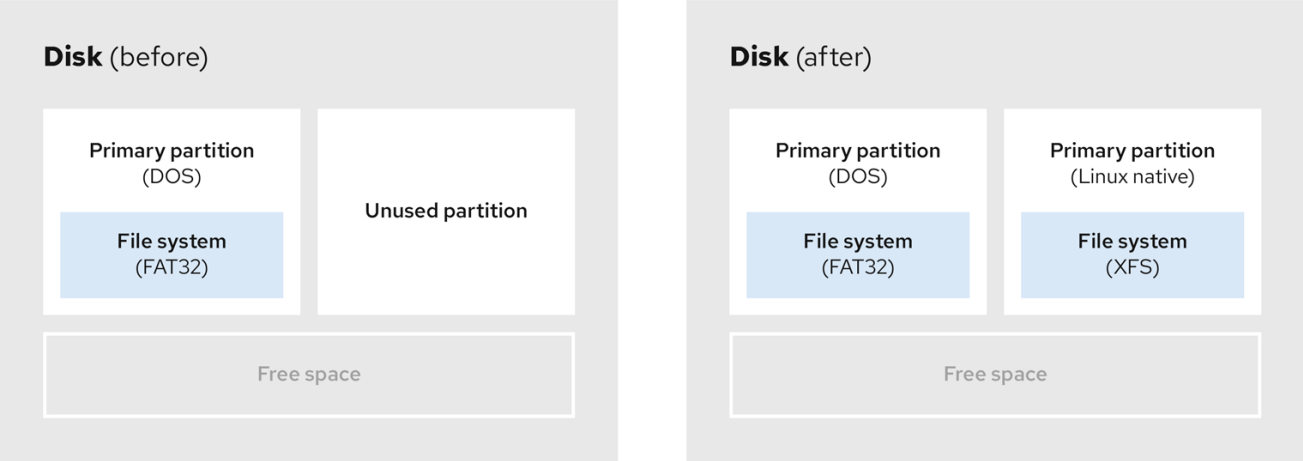
An unused hard disk also falls into this category. The only difference is that *all* the space is not part of any defined partition.

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.

5.2. 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 5.2. 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.

5.3. 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.

5.3.1. 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.

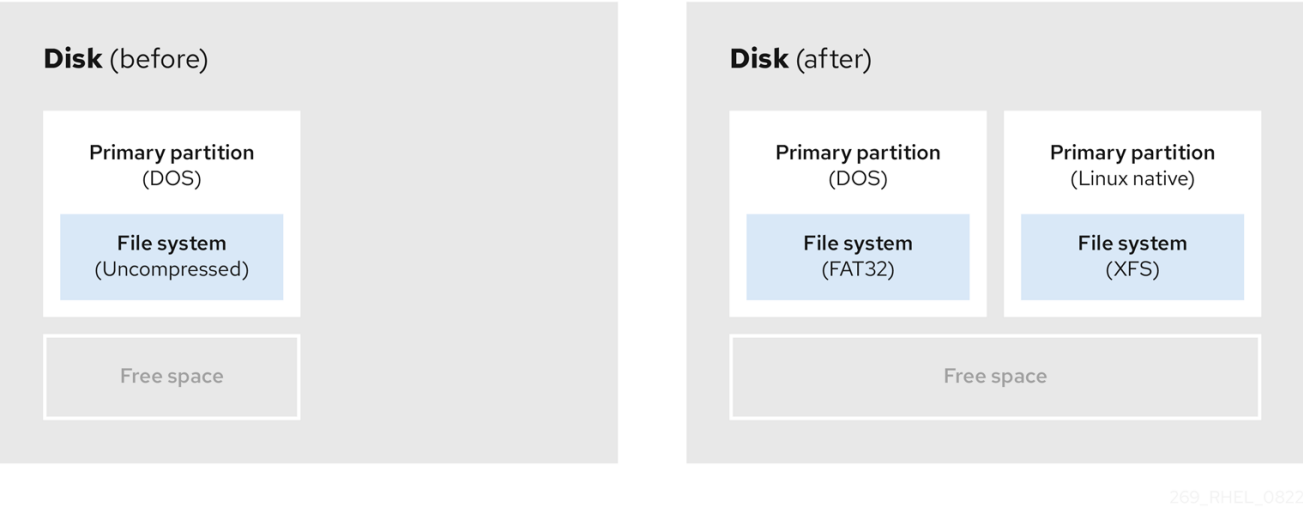
After creating a smaller partition for your existing operating system, you can:

- 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 5.3. Destructive repartitioning action on disk



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

5.3.2. 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.

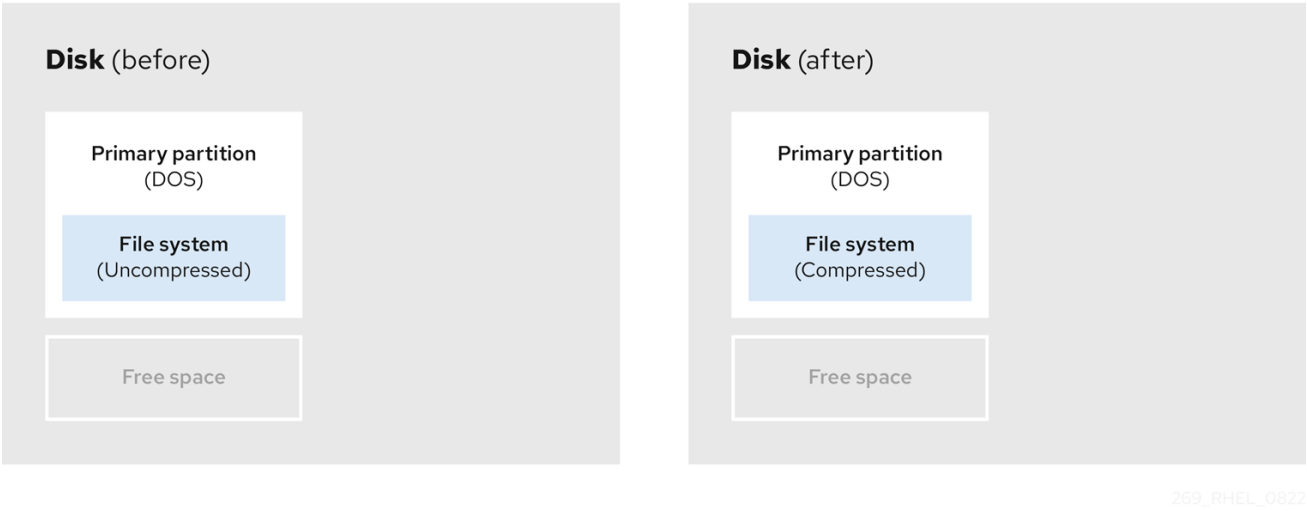
The following is a list of methods, which can help initiate non-destructive repartitioning.

- 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 5.4. Data compression on a disk



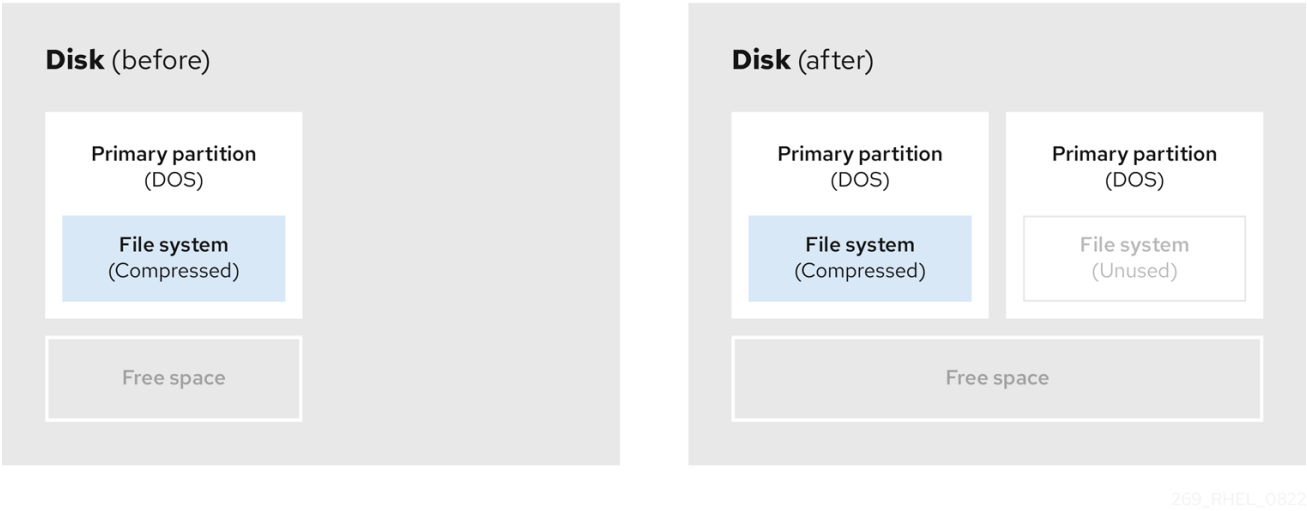
To avoid any possible data loss, create a backup before continuing with the compression process.

- 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 5.5. Partition resizing on a disk

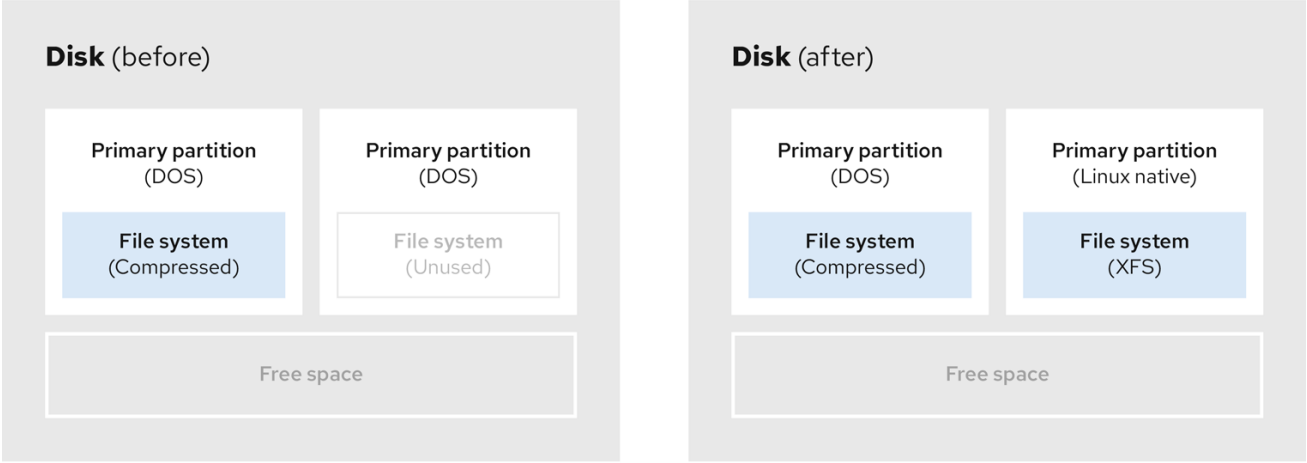


- Optional: Create new partitions

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 5.6. Disk with final partition configuration



269_RHEL_0822

CHAPTER 6. CONFIGURING AN ISCSI TARGET

Red Hat Enterprise Linux uses the **targetcli** shell as a command-line interface to perform the following operations:

- Add, remove, view, and monitor iSCSI storage interconnects to utilize iSCSI hardware.
- Export local storage resources that are backed by either files, volumes, local SCSI devices, or by RAM disks to remote systems.

The **targetcli** tool has a tree-based layout including built-in tab completion, auto-complete support, and inline documentation.

6.1. INSTALLING TARGETCLI

Install the **targetcli** tool to add, monitor, and remove iSCSI storage interconnects .

Procedure

1. Install the **targetcli** tool:

```
# dnf install targetcli
```

2. Start the target service:

```
# systemctl start target
```

3. Configure target to start at boot time:

```
# systemctl enable target
```

4. Open port **3260** in the firewall and reload the firewall configuration:

```
# firewall-cmd --permanent --add-port=3260/tcp
Success
```

```
# firewall-cmd --reload
Success
```

Verification

- View the **targetcli** layout:

```
# targetcli
/> ls
o- /.....................................[...]
  o- backstores..........................[...]
  | o- block.................[Storage Objects: 0]
  | o- fileio................[Storage Objects: 0]
  | o- pscsi.................[Storage Objects: 0]
```

```
| o- ramdisk.............[Storage Objects: 0]
o- iscsi.........................[Targets: 0]
o- loopback......................[Targets: 0]
```

Additional resources

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

6.2. CREATING AN ISCSI TARGET

You can create an iSCSI target to let the iSCSI initiator of the client to access the storage devices on the server. Both targets and initiators have unique identifying names.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.

Procedure

1. Navigate to the iSCSI directory. You can also use the **cd** command to navigate to the iSCSI directory.

```
/> iscsi/
```

2. Use one of the following options to create an iSCSI target:

   a. Creating an iSCSI target using a default target name:

```
/iscsi> create

Created target
iqn.2003-01.org.linux-iscsi.hostname.x8664:sn.78b473f296ff
Created TPG1
```

   b. Creating an iSCSI target using a specific name:

```
/iscsi> create iqn.2006-04.com.example:444

Created target iqn.2006-04.com.example:444
Created TPG1
Here iqn.2006-04.com.example:444 is target_iqn_name
```

   Replace *iqn.2006-04.com.example:444* with the specific target name.

3. Verify the newly created target:

```
/iscsi> ls

o- iscsi.....................................[1 Target]
  o- iqn.2006-04.com.example:444.............[1 TPG]
    o- tpg1.........................[enabled, auth]
      o- acls..............................[0 ACL]
       o- luns..............................[0 LUN]
      o- portals........................[0 Portal]
```

■

Additional resources

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

6.3. ISCSI BACKSTORE

An iSCSI backstore enables support for different methods of storing an exported LUN's data on the local machine. Creating a storage object defines the resources that the backstore uses.

An administrator can choose any of the following backstore devices that Linux-IO (LIO) supports:

fileio backstore

Create a **fileio** storage object if you are using regular files on the local file system as disk images. For creating a **fileio** backstore, see Creating a fileio storage object .

block backstore

Create a **block** storage object if you are using any local block device and logical device. For creating a **block** backstore, see Creating a block storage object .

pscsi backstore

Create a **pscsi** storage object if your storage object supports direct pass-through of SCSI commands. For creating a **pscsi** backstore, see Creating a pscsi storage object .

ramdisk backstore

Create a **ramdisk** storage object if you want to create a temporary RAM backed device. For creating a **ramdisk** backstore, see Creating a Memory Copy RAM disk storage object .

Additional resources

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

6.4. CREATING A FILEIO STORAGE OBJECT

fileio storage objects can support either the **write_back** or **write_thru** operations. The **write_back** operation enables the local file system cache. This improves performance but increases the risk of data loss.

It is recommended to use **write_back=false** to disable the **write_back** operation in favor of the **write_thru** operation.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.

Procedure

1. Navigate to the **fileio**/ from the **backstores**/ directory:

```
/> backstores/fileio
```

2. Create a **fileio** storage object:

■

```
/backstores/fileio> create file1 /tmp/disk1.img 200M write_back=false

Created fileio file1 with size 209715200
```

Verification

- Verify the created **fileio** storage object:

```
/backstores/fileio> ls
```

Additional resources

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

6.5. CREATING A BLOCK STORAGE OBJECT

The block driver allows the use of any block device that appears in the **/sys/block/** directory to be used with Linux-IO (LIO). This includes physical devices, such as HDDs, SSDs, CDs, and DVDs, and logical devices, such as software or hardware RAID volumes, or LVM volumes.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.

Procedure

1. Navigate to the **block/** from the **backstores/** directory:

```
/> backstores/block/
```

2. Create a **block** backstore:

```
/backstores/block> create name=block_backend dev=/dev/sdb

Generating a wwn serial.
Created block storage object block_backend using /dev/sdb.
```

Verification

- Verify the created **block** storage object:

```
/backstores/block> ls
```

Additional resources

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

6.6. CREATING A PSCSI STORAGE OBJECT

You can configure as a backstore any storage object that supports direct pass-through of SCSI commands without SCSI emulation and with an underlying SCSI device that appears with **lsscsi** in the **/proc/scsi/scsi**, such as a SAS hard drive. SCSI-3 and higher is supported with this subsystem.

> **WARNING**
>
> **pscsi** should only be used by advanced users. Advanced SCSI commands such as for Asymmetric Logical Unit Assignment (ALUAs) or Persistent Reservations (for example, those used by VMware ESX, and vSphere) are usually not implemented in the device firmware and can cause malfunctions or crashes. When in doubt, use **block** backstore for production setups instead.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.

Procedure

1. Navigate to the **pscsi**/ from the **backstores**/ directory:

```
/> backstores/pscsi/
```

2. Create a **pscsi** backstore for a physical SCSI device, a TYPE_ROM device using **/dev/sr0** in this example:

```
/backstores/pscsi> create name=pscsi_backend dev=/dev/sr0

Generating a wwn serial.
Created pscsi storage object pscsi_backend using /dev/sr0
```

Verification

- Verify the created **pscsi** storage object:

```
/backstores/pscsi> ls
```

Additional resources

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

6.7. CREATING A MEMORY COPY RAM DISK STORAGE OBJECT

Memory Copy RAM disks (**ramdisk**) provide RAM disks with full SCSI emulation and separate memory mappings using memory copy for initiators. This provides capability for multi-sessions and is particularly useful for fast and volatile mass storage for production purposes.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.

Procedure

1. Navigate to the **ramdisk**/ from the **backstores**/ directory:

```
/> backstores/ramdisk/
```

2. Create a 1GB RAM disk backstore:

```
/backstores/ramdisk> create name=rd_backend size=1GB

Generating a wwn serial.
Created rd_mcp ramdisk rd_backend with size 1GB.
```

Verification

- Verify the created **ramdisk** storage object:

```
/backstores/ramdisk> ls
```

Additional resources

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

6.8. CREATING AN ISCSI PORTAL

You can create an iSCSI portal. This adds an IP address and a port to the target that keeps the target enabled.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.
- An iSCSI target associated with a Target Portal Groups (TPG). For more information, see Creating an iSCSI target.

Procedure

1. Navigate to the TPG directory:

```
/iscsi> iqn.2006-04.com.example:444/tpg1/
```

2. Use one of the following options to create an iSCSI portal:

   a. Creating a default portal uses the default iSCSI port **3260** and allows the target to listen to all IP addresses on that port:

```
/iscsi/iqn.20...mple:444/tpg1> portals/ create

Using default IP port 3260
```

```
Binding to INADDR_Any (0.0.0.0)
Created network portal 0.0.0.0:3260
```

b. Creating a portal using a specific IP address:

```
/iscsi/iqn.20...mple:444/tpg1> portals/ create 192.168.122.137

Using default IP port 3260
Created network portal 192.168.122.137:3260
```

Verification

- Verify the newly created portal:

```
/iscsi/iqn.20...mple:444/tpg1> ls

o- tpg..................................... [enabled, auth]
   o- acls ......................................[0 ACL]
   o- luns ......................................[0 LUN]
   o- portals ................................[1 Portal]
     o- 192.168.122.137:3260......................[OK]
```

Additional resources

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

6.9. CREATING AN ISCSI LUN

Logical unit number (LUN) is a physical device that is backed by the iSCSI backstore. Each LUN has a unique number.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.
- An iSCSI target associated with a Target Portal Groups (TPG). For more information, see Creating an iSCSI target.
- Created storage objects. For more information, see iSCSI Backstore.

Procedure

1. Create LUNs of already created storage objects:

```
/iscsi/iqn.20...mple:444/tpg1> luns/ create /backstores/ramdisk/rd_backend
Created LUN 0.

/iscsi/iqn.20...mple:444/tpg1> luns/ create /backstores/block/block_backend
Created LUN 1.

/iscsi/iqn.20...mple:444/tpg1> luns/ create /backstores/fileio/file1
Created LUN 2.
```

2. Verify the created LUNs:

```
/iscsi/iqn.20...mple:444/tpg1> ls

o- tpg..................................... [enabled, auth]
   o- acls ......................................[0 ACL]
   o- luns ......................................[3 LUNs]
   |  o- lun0.........................[ramdisk/ramdisk1]
   |  o- lun1................[block/block1 (/dev/vdb1)]
   |  o- lun2...................[fileio/file1 (/foo.img)]
   o- portals ................................[1 Portal]
      o- 192.168.122.137:3260......................[OK]
```

Default LUN name starts at **0**.

IMPORTANT

By default, LUNs are created with read-write permissions. If a new LUN is added after ACLs are created, LUN automatically maps to all available ACLs and can cause a security risk. To create a LUN with read-only permissions, see Creating a read-only iSCSI LUN.

3. Configure ACLs. For more information, see Creating an iSCSI ACL .

Additional resources

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

6.10. CREATING A READ-ONLY ISCSI LUN

By default, LUNs are created with read-write permissions. You can create a read-only LUN.

Prerequisites

- Installed and running **targetcli**. For more information, see Installing targetcli.
- An iSCSI target associated with a Target Portal Groups (TPG). For more information, see Creating an iSCSI target.
- Created storage objects. For more information, see iSCSI Backstore.

Procedure

1. Set read-only permissions:

```
/> set global auto_add_mapped_luns=false

Parameter auto_add_mapped_luns is now 'false'.
```

This prevents the auto mapping of LUNs to existing ACLs allowing the manual mapping of LUNs.

2. Navigate to the *initiator_iqn_name* directory:

```
/> iscsi/target_iqn_name/tpg1/acls/initiator_iqn_name/
```

3. Create the LUN:

```
/iscsi/target_iqn_name/tpg1/acls/initiator_iqn_name> create
mapped_lun=next_sequential_LUN_number tpg_lun_or_backstore=backstore
write_protect=1
```

Example:

```
/iscsi/target_iqn_name/tpg1/acls/2006-04.com.example:888> create mapped_lun=1
tpg_lun_or_backstore=/backstores/block/block2 write_protect=1

Created LUN 1.
Created Mapped LUN 1.
```

4. Verify the created LUN:

```
/iscsi/target_iqn_name/tpg1/acls/2006-04.com.example:888> ls
 o- 2006-04.com.example:888 .. [Mapped LUNs: 2]
 | o- mapped_lun0 ............. [lun0 block/disk1 (rw)]
 | o- mapped_lun1 ............. [lun1 block/disk2 (ro)]
```

The mapped_lun1 line now has (**ro**) at the end (unlike mapped_lun0's (**rw**)) stating that it is read-only.

5. Configure ACLs. For more information, see Creating an iSCSI ACL .

Additional resources

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

6.11. CREATING AN ISCSI ACL

The **targetcli** service uses Access Control Lists (ACLs) to define access rules and grant each initiator access to a Logical Unit Number (LUN).

Both targets and initiators have unique identifying names. You must know the unique name of the initiator to configure ACLs. The **/etc/iscsi/initiatorname.iscsi** file, provided by the **iscsi-initiator-utils** package, contains the iSCSI initiator names.

Prerequisites

- The **targetcli** service is installed and running.
- An iSCSI target associated with a Target Portal Groups (TPG).

Procedure

1. Optional: To disable auto mapping of LUNs to ACLs see Creating a read-only iSCSI LUN .
2. Navigate to the acls directory:

```
/> iscsi/target_iqn_name/tpg_name/acls/
```

3. Use one of the following options to create an ACL:

   - Use the *initiator_iqn_name* from the **/etc/iscsi/initiatorname.iscsi** file on the initiator:

     ```
     iscsi/target_iqn_name/tpg_name/acls> create initiator_iqn_name

     Created Node ACL for initiator_iqn_name
     Created mapped LUN 2.
     Created mapped LUN 1.
     Created mapped LUN 0.
     ```

   - Use a *custom_name* and update the initiator to match it:

     ```
     iscsi/target_iqn_name/tpg_name/acls> create custom_name

     Created Node ACL for custom_name
     Created mapped LUN 2.
     Created mapped LUN 1.
     Created mapped LUN 0.
     ```

     For information about updating the initiator name, see Creating an iSCSI intiator.

Verification

- Verify the created ACL:

  ```
  iscsi/target_iqn_name/tpg_name/acls> ls

  o- acls ..................................................[1 ACL]
    o- target_iqn_name ....[3 Mapped LUNs, auth]
      o- mapped_lun0 .............[lun0 ramdisk/ramdisk1 (rw)]
      o- mapped_lun1 ................[lun1 block/block1 (rw)]
      o- mapped_lun2 ................[lun2 fileio/file1 (rw)]
  ```

Additional resources

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

6.12. SETTING UP THE CHALLENGE-HANDSHAKE AUTHENTICATION PROTOCOL FOR THE TARGET

By using the **Challenge-Handshake Authentication Protocol (CHAP)**, users can protect the target with a password. The initiator must be aware of this password to be able to connect to the target.

Prerequisites

- Created iSCSI ACL. For more information, see Creating an iSCSI ACL.

Procedure

1. Set attribute authentication:

```
/iscsi/iqn.20...mple:444/tpg1> set attribute authentication=1

Parameter authentication is now '1'.
```

2. Set **userid** and **password**:

```
/tpg1> set auth userid=redhat
Parameter userid is now 'redhat'.

/iscsi/iqn.20...689dcbb3/tpg1> set auth password=redhat_passwd
Parameter password is now 'redhat_passwd'.
```

3. Navigate to the **acls** directory:

```
/> iscsi/target_iqn_name/tpg1/acls/initiator_iqn_name/
```

4. Set attribute authentication:

```
/iscsi/iqn.20...:605fcc6a48be> set attribute authentication=1
Parameter authentication is now '1'.
```

5. Set **userid** and **password**:

```
/iscsi/iqn.20...:605fcc6a48be> set auth userid=redhat
Parameter userid is now 'redhat'.

/iscsi/iqn.20...:605fcc6a48be> set auth password=redhat_passwd
Parameter password is now 'redhat_passwd'.
```

Additional resources

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

6.13. REMOVING AN ISCSI OBJECT USING TARGETCLI TOOL

You can remove the iSCSI objects by using the **targetcli** tool.

Procedure

1. Log off from the target:

```
# iscsiadm -m node -T iqn.2006-04.com.example:444 -u
```

For more information about how to log in to the target, see Creating an iSCSI initiator .

2. Remove the entire target, including all ACLs, LUNs, and portals:

```
/> iscsi/ delete iqn.2006-04.com.example:444
```

Replace *iqn.2006-04.com.example:444* with the target_iqn_name.

- To remove an iSCSI backstore:

```
/> backstores/backstore-type/ delete block_backend
```

Replace *backstore-type* with either **fileio**, **block**, **pscsi**, or **ramdisk**.

Replace *block_backend* with the *backstore-name* you want to delete.

- To remove parts of an iSCSI target, such as an ACL:

```
/> /iscsi/iqn-name/tpg/acls/ delete iqn.2006-04.com.example:444
```

Verification

- View the changes:

```
/> iscsi/ ls
```

Additional resources

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

CHAPTER 7. CONFIGURING AN ISCSI INITIATOR

An iSCSI initiator forms a session to connect to the iSCSI target. By default, an iSCSI service is lazily started and the service starts after running the **iscsiadm** command. If root is not on an iSCSI device or there are no nodes marked with **node.startup = automatic** then the iSCSI service will not start until an **iscsiadm** command is executed that requires **iscsid** or the **iscsi** kernel modules to be started.

Execute the **systemctl start iscsid** command as root to force the **iscsid** service to run and iSCSI kernel modules to load.

7.1. CREATING AN ISCSI INITIATOR

Create an iSCSI initiator to connect to the iSCSI target to access the storage devices on the server.

Prerequisites

- You have an iSCSI target's hostname and IP address:
  - If you are connecting to a storage target that the external software created, find the target's hostname and IP address from the storage administrator.
  - If you are creating an iSCSI target, see Creating an iSCSI target.

Procedure

1. Install **iscsi-initiator-utils** on client machine:

```
# dnf install iscsi-initiator-utils
```

2. Start the **iscsid** service:

```
# systemctl start iscsid
```

3. Check the initiator name:

```
# cat /etc/iscsi/initiatorname.iscsi

InitiatorName=iqn.2006-04.com.example:888
```

4. If the ACL was given a custom name in Creating an iSCI ACL, update the initiator name to match the ACL:
   a. Open the **/etc/iscsi/initiatorname.iscsi** file and modify the initiator name:

```
# vi /etc/iscsi/initiatorname.iscsi

InitiatorName=custom-name
```

   b. Restart the **iscsid** service:

```
# systemctl restart iscsid
```

5. Discover the target and log in to the target with the displayed target IQN:

```
# iscsiadm -m discovery -t st -p 10.64.24.179
    10.64.24.179:3260,1 iqn.2006-04.com.example:444

# iscsiadm -m node -T iqn.2006-04.com.example:444 -l
    Logging in to [iface: default, target: iqn.2006-04.com.example:444, portal:
10.64.24.179,3260] (multiple)
    Login to [iface: default, target: iqn.2006-04.com.example:444, portal: 10.64.24.179,3260]
successful.
```

Replace *10.64.24.179* with the target-ip-address.

You can use this procedure for any number of initiators connected to the same target if their respective initiator names are added to the ACL as described in the Creating an iSCSI ACL .

6. Find the iSCSI disk name and create a file system on this iSCSI disk:

```
# grep "Attached SCSI" /var/log/messages

# mkfs.ext4 /dev/disk_name
```

Replace *disk_name* with the iSCSI disk name displayed in the **/var/log/messages** file.

7. Mount the file system:

```
# mkdir /mount/point

# mount /dev/disk_name /mount/point
```

Replace */mount/point* with the mount point of the partition.

8. Edit the **/etc/fstab** file to mount the file system automatically when the system boots:

```
# vi /etc/fstab

/dev/disk_name /mount/point ext4 _netdev 0 0
```

Replace *disk_name* with the iSCSI disk name and */mount/point* with the mount point of the partition.

Additional resources

- **targetcli(8)** and **iscsiadm(8)** man pages on your system

7.2. SETTING UP THE CHALLENGE-HANDSHAKE AUTHENTICATION PROTOCOL FOR THE INITIATOR

By using the **Challenge-Handshake Authentication Protocol (CHAP)**, users can protect the target with a password. The initiator must be aware of this password to be able to connect to the target.

Prerequisites

- Created iSCSI initiator. For more information, see Creating an iSCSI initiator .

- Set the **CHAP** for the target. For more information, see Setting up the Challenge-Handshake Authentication Protocol for the target.

Procedure

1. Enable CHAP authentication in the **iscsid.conf** file:

```
# vi /etc/iscsi/iscsid.conf

node.session.auth.authmethod = CHAP
```

   By default, the **node.session.auth.authmethod** is set to **None**

2. Add target **username** and **password** in the **iscsid.conf** file:

```
node.session.auth.username = redhat
node.session.auth.password = redhat_passwd
```

3. Restart the **iscsid** service:

```
# systemctl restart iscsid
```

Additional resources

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

7.3. MONITORING AN ISCSI SESSION BY USING THE ISCSIADM UTILITY

You can monitor the iscsi session by using the **iscsiadm** utility.

By default, an iSCSI service is lazily started and the service starts after running the **iscsiadm** command. If root is not on an iSCSI device or there are no nodes marked with **node.startup = automatic** then the iSCSI service will not start until an **iscsiadm** command is executed that requires **iscsid** or the **iscsi** kernel modules to be started.

Use the **systemctl start iscsid** command as root to force the **iscsid** service to run and iSCSI kernel modules to load.

Procedure

1. Install the **iscsi-initiator-utils** on client machine:

```
# dnf install iscsi-initiator-utils
```

2. Find information about the running sessions:

```
# iscsiadm -m session -P 3
```

   This command displays the session or device state, session ID (sid), some negotiated parameters, and the SCSI devices accessible through the session.

- For shorter output, for example, to display only the **sid-to-node** mapping, run:

```
# iscsiadm -m session -P 0
      or
# iscsiadm -m session

tcp [2] 10.15.84.19:3260,2 iqn.1992-08.com.netapp:sn.33615311
tcp [3] 10.15.85.19:3260,3 iqn.1992-08.com.netapp:sn.33615311
```

  These commands print the list of running sessions in the following format: **driver [sid] target_ip:port,target_portal_group_tag proper_target_name**.

Additional resources

- **/usr/share/doc/iscsi-initiator-utils-version/README** file
- **iscsiadm(8)** man page on your system

7.4. DM MULTIPATH OVERRIDES OF THE DEVICE TIMEOUT

The **recovery_tmo sysfs** option controls the timeout for a particular iSCSI device. The following options globally override the **recovery_tmo** values:

- The **replacement_timeout** configuration option globally overrides the **recovery_tmo** value for all iSCSI devices.
- For all iSCSI devices that are managed by DM Multipath, the **fast_io_fail_tmo** option in DM Multipath globally overrides the **recovery_tmo** value.
  The **fast_io_fail_tmo** option in DM Multipath also overrides the **fast_io_fail_tmo** option in Fibre Channel devices.

The DM Multipath **fast_io_fail_tmo** option takes precedence over **replacement_timeout**. Every time the **multipathd** service is reloaded, it resets **recovery_tmo** to the value of the **fast_io_fail_tmo** configuration option. Use the DM multipath **fast_io_fail_tmo** configuration option to override **recovery_tmo** in devices managed by DM Multipath.

CHAPTER 8. USING FIBRE CHANNEL DEVICES

Red Hat Enterprise Linux 9 provides the following native Fibre Channel drivers:

- **lpfc**
- **qla2xxx**
- **zfcp**

8.1. RE-SCANNING FIBRE CHANNEL LOGICAL UNITS AFTER RESIZING A LUN

If you changed the logical unit number (LUN) size on the external storage, use the **echo** command to update the kernel's view of the size.

Procedure

1. Determine which devices are paths for a **multipath** logical unit:

```
# multipath -ll
```

2. Re-scan Fibre Channel logical units on a system that uses multipathing:

```
$ echo 1 > /sys/block/<device_ID>/device/rescan
```

   Replace ***<device_ID>*** with the ID of your device, for example **sda**.

Additional resources

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

8.2. DETERMINING THE LINK LOSS BEHAVIOR OF DEVICE USING FIBRE CHANNEL

If a driver implements the Transport **dev_loss_tmo** callback, access attempts to a device through a link will be blocked when a transport problem is detected.

Procedure

- Determine the state of a remote port:

```
$ cat /sys/class/fc_remote_ports/rport-host:bus:remote-port/port_state
```

  This command returns one of the following output:

  - **Blocked** when the remote port along with devices accessed through it are blocked.
  - **Online** if the remote port is operating normally
    If the problem is not resolved within **dev_loss_tmo** seconds, the **rport** and devices will be unblocked. All I/O running on that device along with any new I/O sent to that device will fail.

When a link loss exceeds **dev_loss_tmo**, the **scsi_device** and **sd_N_** devices are removed. Typically, the Fibre Channel class does not alter the device, for example, **/dev/sda** remains **/dev/sda**. This is because the target binding is saved by the Fibre Channel driver and when the target port returns, the SCSI addresses are recreated faithfully. However, this cannot be guaranteed, the device will be restored only if no additional change on in-storage box configuration of LUNs is made.

Additional resources

- **multipath.conf(5)** man page on your system
- Recommended tuning at scsi,multipath and at application layer while configuring Oracle RAC cluster (Red Hat Knowledgebase)

8.3. FIBRE CHANNEL CONFIGURATION FILES

The following is the list of configuration files in the **/sys/class/** directory that provide the user-space API to Fibre Channel.

The items use the following variables:

H

Host number

B

Bus number

T

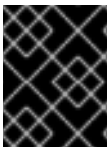
Target

L

Logical unit (LUNs)

R

Remote port number



IMPORTANT

Consult your hardware vendor before changing any of the values described in this section, if your system is using multipath software.

Transport configuration in /sys/class/fc_transport/target*H*:*B*:*T*/

port_id

24-bit port ID/address

node_name

64-bit node name

port_name

64-bit port name

Remote port configuration in /sys/class/fc_remote_ports/rport-*H*:*B*-*R*/

- **port_id**

- **node_name**
- **port_name**
- **dev_loss_tmo**
  Controls when the scsi device gets removed from the system. After **dev_loss_tmo** triggers, the scsi device is removed. In the **multipath.conf** file , you can set **dev_loss_tmo** to **infinity**.

  In Red Hat Enterprise Linux 9, if you do not set the **fast_io_fail_tmo** option, **dev_loss_tmo** is capped to **600** seconds. By default, **fast_io_fail_tmo** is set to **5** seconds in Red Hat Enterprise Linux 9 if the **multipathd** service is running; otherwise, it is set to **off**.
- **fast_io_fail_tmo**
  Specifies the number of seconds to wait before it marks a link as "bad". Once a link is marked bad, existing running I/O or any new I/O on its corresponding path fails.

  If I/O is in a blocked queue, it will not be failed until **dev_loss_tmo** expires and the queue is unblocked.

  If **fast_io_fail_tmo** is set to any value except off, **dev_loss_tmo** is uncapped. If **fast_io_fail_tmo** is set to off, no I/O fails until the device is removed from the system. If **fast_io_fail_tmo** is set to a number, I/O fails immediately when the **fast_io_fail_tmo** timeout triggers.

Host configuration in **/sys/class/fc_host/host*H*/**

- **port_id**
- **node_name**
- **port_name**
- **issue_lip**
  Instructs the driver to rediscover remote ports.

CHAPTER 9. OVERVIEW OF NVME OVER FABRIC DEVICES

Non-volatile Memory Express™ (NVMe™) is an interface that allows host software utility to communicate with solid state drives.

Use the following types of fabric transport to configure NVMe over fabric devices:

NVMe over Remote Direct Memory Access (NVMe/RDMA)

For information about how to configure NVMe™/RDMA, see Configuring NVMe over fabrics using NVMe/RDMA.

NVMe over Fibre Channel (NVMe/FC)

For information about how to configure NVMe™/FC, see Configuring NVMe over fabrics using NVMe/FC.

NVMe over TCP (NVMe/TCP)

For information about how to configure NVMe™/TCP, see Configuring NVMe over fabrics using NVMe/TCP.

When using NVMe over fabrics, the solid-state drive does not have to be local to your system; it can be configured remotely through a NVMe over fabrics devices.

CHAPTER 10. CONFIGURING NVME OVER FABRICS USING NVME/RDMA

In a Non-volatile Memory Express™ (NVMe™) over RDMA (NVMe™/RDMA) setup, you configure an NVMe controller and an NVMe initiator.

10.1. SETTING UP AN NVME/RDMA CONTROLLER USING CONFIGFS

You can configure a Non-volatile Memory Express™ (NVMe™) over RDMA (NVMe™/RDMA) controller by using **configfs**.

Prerequisites

- Verify that you have a block device to assign to the **nvmet** subsystem.

Procedure

1. Create the **nvmet-rdma** subsystem:

```
# modprobe nvmet-rdma

# mkdir /sys/kernel/config/nvmet/subsystems/testnqn

# cd /sys/kernel/config/nvmet/subsystems/testnqn
```

   Replace *testnqn* with the subsystem name.

2. Allow any host to connect to this controller:

```
# echo 1 > attr_allow_any_host
```

3. Configure a namespace:

```
# mkdir namespaces/10

# cd namespaces/10
```

   Replace *10* with the namespace number

4. Set a path to the NVMe device:

```
# echo -n /dev/nvme0n1 > device_path
```

5. Enable the namespace:

```
# echo 1 > enable
```

6. Create a directory with an NVMe port:

```
# mkdir /sys/kernel/config/nvmet/ports/1

# cd /sys/kernel/config/nvmet/ports/1
```

7. Display the IP address of *mlx5_ib0*:

```
# ip addr show mlx5_ib0

8: mlx5_ib0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 4092 qdisc mq state UP
group default qlen 256
    link/infiniband 00:00:06:2f:fe:80:00:00:00:00:00:00:e4:1d:2d:03:00:e7:0f:f6 brd
00:ff:ff:ff:ff:12:40:1b:ff:ff:00:00:00:00:00:00:ff:ff:ff:ff
    inet 172.31.0.202/24 brd 172.31.0.255 scope global noprefixroute mlx5_ib0
       valid_lft forever preferred_lft forever
    inet6 fe80::e61d:2d03:e7:ff6/64 scope link noprefixroute
       valid_lft forever preferred_lft forever
```

8. Set the transport address for the controller:

```
# echo -n 172.31.0.202 > addr_traddr
```

9. Set RDMA as the transport type:

```
# echo rdma > addr_trtype

# echo 4420 > addr_trsvcid
```

10. Set the address family for the port:

```
# echo ipv4 > addr_adrfam
```

11. Create a soft link:

```
# ln -s /sys/kernel/config/nvmet/subsystems/testnqn
/sys/kernel/config/nvmet/ports/1/subsystems/testnqn
```

Verification

- Verify that the NVMe controller is listening on the given port and ready for connection requests:

```
# dmesg | grep "enabling port"
[ 1091.413648] nvmet_rdma: enabling port 1 (172.31.0.202:4420)
```

Additional resources

- **nvme(1)** man page on your system

10.2. SETTING UP THE NVME/RDMA CONTROLLER USING NVMETCLI

You can configure the Non-volatile Memory Express™ (NVMe™) over RDMA (NVMe™/RDMA) controller by using the **nvmetcli** utility. The **nvmetcli** utility provides a command line and an interactive shell option.

Prerequisites

- Verify that you have a block device to assign to the **nvmet** subsystem.

- Execute the following **nvmetcli** operations as a root user.

Procedure

1. Install the **nvmetcli** package:

```
# dnf install nvmetcli
```

2. Download the **rdma.json** file:

```
# wget
http://git.infradead.org/users/hch/nvmetcli.git/blob_plain/0a6b088db2dc2e5de11e6f23f
1e890e4b54fee64:/rdma.json
```

3. Edit the **rdma.json** file and change the **traddr** value to **172.31.0.202**.

4. Setup the controller by loading the NVMe controller configuration file:

```
# nvmetcli restore rdma.json
```

NOTE

If the NVMe controller configuration file name is not specified, the **nvmetcli** uses the **/etc/nvmet/config.json** file.

Verification

- Verify that the NVMe controller is listening on the given port and ready for connection requests:

```
# dmesg | tail -1
[ 4797.132647] nvmet_rdma: enabling port 2 (172.31.0.202:4420)
```

- Optional: Clear the current NVMe controller:

```
# nvmetcli clear
```

Additional resources

- **nvmetcli** and **nvme(1)** man pages on your system

10.3. CONFIGURING AN NVME/RDMA HOST

You can configure a Non-volatile Memory Express™ (NVMe™) over RDMA (NVMe™/RDMA) host by using the NVMe management command-line interface (**nvme-cli**) tool.

Procedure

1. Install the **nvme-cli** tool:

```
# dnf install nvme-cli
```

2. Load the **nvme-rdma** module if it is not loaded:

```
# modprobe nvme-rdma
```

3. Discover available subsystems on the NVMe controller:

```
# nvme discover -t rdma -a 172.31.0.202 -s 4420

Discovery Log Number of Records 1, Generation counter 2
=====Discovery Log Entry 0======
trtype:  rdma
adrfam:  ipv4
subtype: nvme subsystem
treq:    not specified, sq flow control disable supported
portid:  1
trsvcid: 4420
subnqn:  testnqn
traddr:  172.31.0.202
rdma_prtype: not specified
rdma_qptype: connected
rdma_cms:    rdma-cm
rdma_pkey: 0x0000
```

4. Connect to the discovered subsystems:

```
# nvme connect -t rdma -n testnqn -a 172.31.0.202 -s 4420

# lsblk
NAME                        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda                           8:0    0 465.8G  0 disk
 ├──sda1                        8:1    0     1G  0 part /boot
 └──sda2                        8:2    0 464.8G  0 part
   ├──rhel_rdma--virt--03-root 253:0    0    50G  0 lvm  /
   ├──rhel_rdma--virt--03-swap 253:1    0     4G  0 lvm  [SWAP]
   └──rhel_rdma--virt--03-home 253:2    0 410.8G  0 lvm  /home
nvme0n1

# cat /sys/class/nvme/nvme0/transport
rdma
```

Replace *testnqn* with the NVMe subsystem name.

Replace *172.31.0.202* with the controller IP address.

Replace *4420* with the port number.

Verification

- List the NVMe devices that are currently connected:

```
# nvme list
```

- Optional: Disconnect from the controller:

```
# nvme disconnect -n testnqn
NQN:testnqn disconnected 1 controller(s)

# lsblk
NAME                        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda                           8:0    0 465.8G  0 disk
 ├──sda1                        8:1    0     1G  0 part /boot
 └──sda2                        8:2    0 464.8G  0 part
   ├──rhel_rdma--virt--03-root 253:0    0    50G  0 lvm  /
   ├──rhel_rdma--virt--03-swap 253:1    0     4G  0 lvm  [SWAP]
   └──rhel_rdma--virt--03-home 253:2    0 410.8G  0 lvm  /home
```

Additional resources

- **nvme(1)** man page on your system

10.4. NEXT STEPS

- Enabling multipathing on NVMe devices

CHAPTER 11. CONFIGURING NVME OVER FABRICS USING NVME/FC

The Non-volatile Memory Express™ (NVMe™) over Fibre Channel (NVMe™/FC) transport is fully supported in host mode when used with certain Broadcom Emulex and Marvell Qlogic Fibre Channel adapters.

11.1. CONFIGURING THE NVME HOST FOR BROADCOM ADAPTERS

You can configure a Non-volatile Memory Express™ (NVMe™) host with Broadcom adapters by using the NVMe management command-line interface (**nvme-cli**) utility.

Procedure

1. Install the **nvme-cli** utility:

```
# dnf install nvme-cli
```

   This creates the **hostnqn** file in the **/etc/nvme/** directory. The **hostnqn** file identifies the NVMe host.

2. Find the World Wide Node Name (WWNN) and World Wide Port Name (WWPN) identifiers of the local and remote ports:

```
# cat /sys/class/scsi_host/host*/nvme_info

NVME Host Enabled
XRI Dist lpfc0 Total 6144 IO 5894 ELS 250
NVME LPORT lpfc0 WWPN x10000090fae0b5f5 WWNN x20000090fae0b5f5 DID x010f00
ONLINE
NVME RPORT       WWPN x204700a098cbcac6 WWNN x204600a098cbcac6 DID x01050e
TARGET DISCSRVC ONLINE

NVME Statistics
LS: Xmt 000000000e Cmpl 000000000e Abort 00000000
LS XMIT: Err 00000000  CMPL: xb 00000000 Err 00000000
Total FCP Cmpl 00000000000008ea Issue 00000000000008ec OutIO 0000000000000002
    abort 00000000 noxri 00000000 nondlp 00000000 qdepth 00000000 wqerr 00000000 err
00000000
FCP CMPL: xb 00000000 Err 00000000
```

   Using these **host-traddr** and **traddr** values, find the subsystem NVMe Qualified Name (NQN):

```
# nvme discover --transport fc \
              --traddr nn-0x204600a098cbcac6:pn-0x204700a098cbcac6 \
              --host-traddr nn-0x20000090fae0b5f5:pn-0x10000090fae0b5f5

Discovery Log Number of Records 2, Generation counter 49530
=====Discovery Log Entry 0======
trtype:  fc
adrfam:  fibre-channel
subtype: nvme subsystem
treq:    not specified
```

```
portid:  0
trsvcid: none
subnqn:  nqn.1992-
08.com.netapp:sn.e18bfca87d5e11e98c0800a098cbcac6:subsystem.st14_nvme_ss_1_1
traddr:  nn-0x204600a098cbcac6:pn-0x204700a098cbcac6
```

Replace *nn-0x204600a098cbcac6:pn-0x204700a098cbcac6* with the **traddr**.

Replace *nn-0x20000090fae0b5f5:pn-0x10000090fae0b5f5* with the **host-traddr**.

3. Connect to the NVMe controller using the **nvme-cli**:

```
# nvme connect --transport fc \
        --traddr nn-0x204600a098cbcac6:pn-0x204700a098cbcac6 \
        --host-traddr nn-0x20000090fae0b5f5:pn-0x10000090fae0b5f5 \
        -n nqn.1992-
08.com.netapp:sn.e18bfca87d5e11e98c0800a098cbcac6:subsystem.st14_nvme_ss_1_
1 \
        -k 5
```

NOTE

If you see the **keep-alive timer (5 seconds) expired!** error when a connection time exceeds the default keep-alive timeout value, increase it using the **-k** option. For example, you can use, **-k 7**.

Here,

Replace *nn-0x204600a098cbcac6:pn-0x204700a098cbcac6* with the **traddr**.

Replace *nn-0x20000090fae0b5f5:pn-0x10000090fae0b5f5* with the **host-traddr**.

Replace *nqn.1992-08.com.netapp:sn.e18bfca87d5e11e98c0800a098cbcac6:subsystem.st14_nvme_ss_1_1* with the ***subnqn***.

Replace *5* with the keep-alive timeout value in seconds.

Verification

- List the NVMe devices that are currently connected:

```
# nvme list
Node             SN                   Model                                    Namespace Usage
Format           FW Rev
---------------- -------------------- ---------------------------------------- --------- --------------------------
- ---------------- --------
/dev/nvme0n1     80BgLFM7xMJbAAAAAAAC NetApp ONTAP Controller                   1
107.37  GB / 107.37  GB      4 KiB +  0 B   FFFFFFFF


# lsblk |grep nvme
nvme0n1                 259:0    0   100G  0 disk
```

Additional resources

- **nvme(1)** man page on your system

11.2. CONFIGURING THE NVME HOST FOR QLOGIC ADAPTERS

You can configure a Non-volatile Memory Express™ (NVMe™) host with Qlogic adapters by using the NVMe management command-line interface (**nvme-cli**) utility.

Procedure

1. Install the **nvme-cli** utility:

```
# dnf install nvme-cli
```

   This creates the **hostnqn** file in the **/etc/nvme/** directory. The **hostnqn** file identifies the NVMe host.

2. Reload the **qla2xxx** module:

```
# modprobe -r qla2xxx
# modprobe qla2xxx
```

3. Find the World Wide Node Name (WWNN) and World Wide Port Name (WWPN) identifiers of the local and remote ports:

```
# dmesg |grep traddr

[    6.139862] qla2xxx [0000:04:00.0]-ffff:0: register_localport: host-traddr=nn-
0x20000024ff19bb62:pn-0x21000024ff19bb62 on portID:10700
[    6.241762] qla2xxx [0000:04:00.0]-2102:0: qla_nvme_register_remote: traddr=nn-
0x203b00a098cbcac6:pn-0x203d00a098cbcac6 PortID:01050d
```

   Using these **host-traddr** and **traddr** values, find the subsystem NVMe Qualified Name (NQN):

```
# nvme discover --transport fc \
            --traddr nn-0x203b00a098cbcac6:pn-0x203d00a098cbcac6 \
            --host-traddr nn-0x20000024ff19bb62:pn-0x21000024ff19bb62

Discovery Log Number of Records 2, Generation counter 49530
=====Discovery Log Entry 0======
trtype:  fc
adrfam:  fibre-channel
subtype: nvme subsystem
treq:    not specified
portid:  0
trsvcid: none
subnqn:  nqn.1992-
08.com.netapp:sn.c9ecc9187b1111e98c0800a098cbcac6:subsystem.vs_nvme_multipath_1_su
bsystem_468
traddr:  nn-0x203b00a098cbcac6:pn-0x203d00a098cbcac6
```

   Replace *nn-0x203b00a098cbcac6:pn-0x203d00a098cbcac6* with the **traddr**.

Replace *nn-0x20000024ff19bb62:pn-0x21000024ff19bb62* with the **host-traddr**.

4. Connect to the NVMe controller using the **nvme-cli** tool:

```
# nvme connect --transport fc \
        --traddr nn-0x203b00a098cbcac6:pn-0x203d00a098cbcac6 \
        --host-traddr nn-0x20000024ff19bb62:pn-0x21000024ff19bb62 \
        -n nqn.1992-
08.com.netapp:sn.c9ecc9187b1111e98c0800a098cbcac6:subsystem.vs_nvme_multipat
h_1_subsystem_468\
        -k 5
```

NOTE

If you see the **keep-alive timer (5 seconds) expired!** error when a connection time exceeds the default keep-alive timeout value, increase it using the **-k** option. For example, you can use, **-k 7**.

Here,

Replace *nn-0x203b00a098cbcac6:pn-0x203d00a098cbcac6* with the **traddr**.

Replace *nn-0x20000024ff19bb62:pn-0x21000024ff19bb62* with the **host-traddr**.

Replace *nqn.1992-08.com.netapp:sn.c9ecc9187b1111e98c0800a098cbcac6:subsystem.vs_nvme_multipath_1_subsyste* with the ***subnqn***.

Replace *5* with the keep-live timeout value in seconds.

Verification

- List the NVMe devices that are currently connected:

```
# nvme list
Node          SN                   Model                                    Namespace Usage
Format         FW Rev
---------------- -------------------- ---------------------------------------- --------- -------------------------
- ---------------- --------
/dev/nvme0n1     80BgLFM7xMJbAAAAAAAC NetApp ONTAP Controller                 1
107.37  GB / 107.37  GB      4 KiB +  0 B   FFFFFFFF

# lsblk |grep nvme
nvme0n1                 259:0    0   100G  0 disk
```

Additional resources

- **nvme(1)** man page on your system

11.3. NEXT STEPS

- Enabling multipathing on NVMe devices

CHAPTER 12. CONFIGURING NVME OVER FABRICS USING NVME/TCP

In a Non-volatile Memory Express™ (NVMe™) over TCP (NVMe/TCP) setup, the host mode is fully supported and the controller setup is not supported.

Red Hat does not support the NVMe Target (**nvmet**) functionality. Consult your storage manufacturer's documentation for instructions about how to configure your NVMe over Fabrics block storage target device.

NOTE

In RHEL 9, the native NVMe multipathing is enabled by default. Enabling DM multipathing is not supported with NVMe/TCP.

12.1. CONFIGURING AN NVME/TCP HOST

You can configure a Non-volatile Memory Express™ (NVMe™) over TCP (NVMe/TCP) host by using the NVMe management command-line interface (**nvme-cli**) tool.

Procedure

1. Install the **nvme-cli** tool:

```
# dnf install nvme-cli
```

   This tool creates the **hostnqn** file in the **/etc/nvme/** directory, which identifies the NVMe host.

2. Find the nvme **hostid** and **hostnqn**:

```
# cat /etc/nvme/hostnqn
nqn.2014-08.org.nvmexpress:uuid:8ae2b12c-3d28-4458-83e3-658e571ed4b8

# cat /etc/nvme/hostid
09e2ce17-ccc9-412d-8dcf-2b0a1d581ee3
```

   Use the **hostid** and **hostnqn** values to configure the NVMe/TCP controller.

3. Check the status of the controller:

```
# nmcli device show ens6
GENERAL.DEVICE:                         ens6
GENERAL.TYPE:                           ethernet
GENERAL.HWADDR:                         52:57:02:12:02:02
GENERAL.MTU:                            1500
GENERAL.STATE:                          30 (disconnected)
GENERAL.CONNECTION:                     --
GENERAL.CON-PATH:                       --
WIRED-PROPERTIES.CARRIER:               on
```

4. Configure the host network for a newly installed Ethernet controller with a static IP address:

```
# nmcli connection add con-name ens6 ifname ens6 type ethernet ip4 192.168.101.154/24
gw4 192.168.101.1
```

Here, replace *192.168.101.154* with the host IP address.

```
# nmcli connection mod ens6 ipv4.method manual
# nmcli connection up ens6
```

Since a new network is created to connect the NVMe/TCP host to the NVMe/TCP controller, execute this step on the controller too.

Verification

- Verify if the newly created host network works correctly:

```
# nmcli device show ens6
GENERAL.DEVICE:                         ens6
GENERAL.TYPE:                           ethernet
GENERAL.HWADDR:                         52:57:02:12:02:02
GENERAL.MTU:                            1500
GENERAL.STATE:                          100 (connected)
GENERAL.CONNECTION:                     ens6
GENERAL.CON-PATH:                       /org/freedesktop/NetworkManager/ActiveConnection/5
WIRED-PROPERTIES.CARRIER:               on
IP4.ADDRESS[1]:                         192.168.101.154/24
IP4.GATEWAY:                            192.168.101.1
IP4.ROUTE[1]:                           dst = 192.168.101.0/24, nh = 0.0.0.0, mt = 101
IP4.ROUTE[2]:                           dst = 192.168.1.1/32, nh = 0.0.0.0, mt = 101
IP4.ROUTE[3]:                           dst = 0.0.0.0/0, nh = 192.168.1.1, mt = 101
IP6.ADDRESS[1]:                         fe80::27ce:dde1:620:996c/64
IP6.GATEWAY:                            --
IP6.ROUTE[1]:                           dst = fe80::/64, nh = ::, mt = 101
```

Additional resources

- **nvme(1)** man page on your system

12.2. CONNECTING THE NVME/TCP HOST TO THE NVME/TCP CONTROLLER

Connect the NVMe™ over TCP (NVMe/TCP) host to the NVMe/TCP controller system to verify that the NVMe/TCP host can now access the namespace.

NOTE

The NVMe/TCP controller (**nvmet-tcp**) module is not supported.

Prerequisites

- You have configured an NVMe/TCP host. For more information, see Configuring an NVMe/TCP host.

- You have configured an NVMe/TCP controller using external storage software and the network is configured on the controller. In this procedure, *192.168.101.55* is the IP address of NVMe/TCP controller.

Procedure

1. Load the **nvme-tcp** module if not already:

```
# modprobe nvme-tcp
```

2. Discover the available subsystems on the NVMe controller:

```
# nvme discover --transport=tcp --traddr=192.168.101.55 --host-traddr=192.168.101.154 --
trsvcid=8009

Discovery Log Number of Records 2, Generation counter 7
=====Discovery Log Entry 0======
trtype:  tcp
adrfam:  ipv4
subtype: current discovery subsystem
treq: not specified, sq flow control disable supported
portid:  2
trsvcid: 8009
subnqn:  nqn.2014-08.org.nvmexpress.discovery
traddr:  192.168.101.55
eflags:  not specified
sectype: none
=====Discovery Log Entry 1======
trtype:  tcp
adrfam:  ipv4
subtype: nvme subsystem
treq: not specified, sq flow control disable supported
portid:  2
trsvcid: 8009
subnqn:  nqn.2014-08.org.nvmexpress:uuid:0c468c4d-a385-47e0-8299-6e95051277db
traddr:  192.168.101.55
eflags:  not specified
sectype: none
```

   Here, *192.168.101.55* is the NVMe/TCP controller IP address and *192.168.101.154* is the NVMe/TCP host IP address.

3. Configure the **/etc/nvme/discovery.conf** file to add the parameters used in the **nvme discover** command :

```
# echo "--transport=tcp --traddr=192.168.101.55 --host-traddr=192.168.101.154 --
trsvcid=8009" >> /etc/nvme/discovery.conf
```

4. Connect the NVMe/TCP host to the controller system:

```
# nvme connect-all
```

5. Make the NVMe/TCP connection persistent:

```
# systemctl enable nvmf-autoconnect.service
```

Verification

- Verify that the NVMe/TCP host can access the namespace:

```
# nvme list-subsys

nvme-subsys3 - NQN=nqn.2014-08.org.nvmexpress:uuid:0c468c4d-a385-47e0-8299-
6e95051277db
\
 +- nvme3 tcp traddr=192.168.101.55,trsvcid=8009,host_traddr=192.168.101.154 live
optimized

# nvme list
Node             Generic          SN               Model                                    Namespace Usage
Format       FW Rev
--------------------- --------------------- -------------------- ---------------------------------------- --------
- -------------------------- ---------------- --------
/dev/nvme3n1     /dev/ng3n1       d93a63d394d043ab4b74 Linux                                    1
21.47  GB /  21.47  GB    512   B +  0 B   5.18.5-2
```

Additional resources

- **nvme(1)** man page on your system

12.3. CONFIGURING NVME HOST AUTHENTICATION

To establish an authenticated connection with an NVMe over Fabrics (NVMe-oF) controller, you can configure authentication on a Non-volatile Memory Express (NVMe) host. NVMe authentication uses a shared secret or a pair of secrets, with a challenge-response protocol, for example, NVMe DH-HMAC-CHAP.

NOTE

NVMe authentication is supported only for the NVMe/TCP transport type. This feature is not available for other transports, such as NVMe over Remote Direct Memory Access (NVMe/RDMA) or NVMe over Fibre Channel (NVMe/FC).

Prerequisites

- The **nvme-cli** package is installed.
- You know the Host NVMe Qualified Name (Host NQN) and the Subsystem NVMe Qualified Name (Subsystem NQN), if using bi-directional authentication. To see the default Host NQN for your system, run **nvme show-hostnqnq**.

Procedure

1. Generate an authentication secret:
   a. For the host:

```
# hostkey=$(nvme gen-dhchap-key -n ${HOSTNQN})
```

b. For the subsystem:

```
# ctrlkey= $(nvme gen-dhchap-key -n ${SUBSYSTEM})
```

2. Configure the host for authentication:

```
# nvme connect -t tcp -n ${SUBSYSTEM} -a ${TRADDR} -s 4420 --dhchap-
secret=${hostkey} --dhchap-ctrl-secret=${ctrlkey}
```

This provides the authentication secrets to the **nvme-connect** utility so that it can authenticate and establish a connection to the target.

- Optional: To enable automated logins, set up persistent NVMe fabrics configuration. To do so, add the **--dhchap-secret** and **--dhchap-ctrl-secret** parameters to **/etc/nvme/discovery.conf** or **/etc/nvme/config.json**.

Verification

- Verify that the NVMe storage is attached:

```
# nvme list
```

This displays the list of NVMe devices currently attached to the host. Verify that the expected storage is listed, indicating the connection to the storage server is successful.

12.4. CONFIGURING AN NVME/TCP HOST USING TLS WITH PRE-SHARED-KEYS

You can configure a Non-volatile Memory Express™ (NVMe™) over TCP (NVMe™/TCP) host while enabling TLS encryption. The NVMe/TLS configuration uses a TLS Pre-Shared Key (PSK).

The NVM Express TCP Transport Specification specifies a PSK Interchange Format for exchanging PSK information between systems. You can use **nvme-cli** or other methods to generate PSKs in this format (for example, create it on a storage target, see your vendor documentation). These configured PSKs are then used by **nvme-cli** to derive retained PSKs, which are inserted into a kernel keyring for use.

IMPORTANT

NVMe/TCP using TLS is a Technology Preview feature only. Technology Preview features are not supported with Red Hat production service level agreements (SLAs) and might not be functionally complete. Red Hat does not recommend using them in production. These features provide early access to upcoming product features, enabling customers to test functionality and provide feedback during the development process.

For more information about the support scope of Red Hat Technology Preview features, see Technology Preview Features Support Scope .

Prerequisites

- The **nvme_tcp** kernel module is installed on your system.

- The following packages are installed on your system:
  - **nvme-cli**
  - **ktls-utils**
- You have the Subsystem NVMe Qualified Name (Subsystem NQN).
- You have root permissions on the system.

Procedure

1. Configure Pre-Shared-Key Keyring.
   a. Identify Host NQN:

   ```
   # HOSTNQN=$(nvme show-hostnqn)
   ```

   b. Generate and copy a newly configured PSK:

   ```
   # PSK=$(nvme gen-tls-key)
   ```

   ```
   # echo $PSK
   ```

   c. Configure Pre-Shared-Key Keyring:

   ```
   # nvme check-tls-key --insert --hostnqn=${HOSTNQN} --subsysnqn=${SUBSYSTEM} --
   keydata=${PSK} --identity=1
   ```

2. Configure the **tlshd** service.
   a. Add the keyring name to the **/etc/tlshd.conf** configuration file:

   ```
   ...
   [authenticate]
   keyring=.nvme
   ...
   ```

   b. Restart the **tlshd** service:

   ```
   # systemctl restart tlshd
   ```

3. Enable TLS for NVMe fabrics connections:

   ```
   # nvme discover -t tcp --tls -a ${TRADDR} -s 4420
   ```

   ```
   # nvme connect -t tcp --tls -a ${TRADDR} -s 4420 -n ${SUBSYSTEM}
   ```

Verification

- List the NVMe devices that are currently connected:

  ```
  # nvme list
  ```

```
Node             Generic          SN               Model                                    Namespace  Usage
Format       FW Rev
---------------------- ---------------------- -------------------- ---------------------------------------- --------
-- -------------------------- ---------------- --------
/dev/nvme4n1       /dev/ng4n1         81JJAJTOpnmUAAAAAAAB NetApp ONTAP Controller
0x1      16.17  GB / 161.06  GB   4 KiB +  0 B   9.16.1
```

12.5. ADDITIONAL RESOURCES

- NVMe Specifications

CHAPTER 13. ENABLING MULTIPATHING ON NVME DEVICES

You can multipath Non-volatile Memory Express™ (NVMe™) devices that are connected to your system over a fabric transport, such as Fibre Channel (FC). You can select between multiple multipathing solutions.

13.1. NATIVE NVME MULTIPATHING AND DM MULTIPATH

Non-volatile Memory Express™ (NVMe™) devices support a native multipathing functionality. When configuring multipathing on NVMe, you can select between the standard DM Multipath framework and the native NVMe multipathing.

Both DM Multipath and native NVMe multipathing support the Asymmetric Namespace Access (ANA) multipathing scheme of NVMe devices. ANA identifies optimized paths between the controller and the host, and improves performance.

When native NVMe multipathing is enabled, it applies globally to all NVMe devices. It can provide higher performance, but does not contain all of the functionality that DM Multipath provides. For example, native NVMe multipathing supports only the **numa** and **round-robin** path selection methods.

By default, NVMe multipathing is enabled in Red Hat Enterprise Linux 9 and is the recommended multipathing solution.

13.2. ENABLING DM MULTIPATH ON NVME DEVICES

The default kernel setting for the **nvme_core.multipath** option is set to **Y**, which means that the native Non-volatile Memory Express™ (NVMe™) multipathing is enabled. You can enable DM Multipath on connected NVMe devices by disabling native NVMe multipathing.

Prerequisites

- The NVMe devices are connected to your system. For more information, see Overview of NVMe over fabric devices.

Procedure

1. Check if the native NVMe multipathing is enabled:

```
# cat /sys/module/nvme_core/parameters/multipath
```

   The command displays one of the following:

   N

   Native NVMe multipathing is disabled.

   Y

   Native NVMe multipathing is enabled.

2. If the native NVMe multipathing is enabled, disable it by using one of the following methods:

   - Using a kernel option:

     a. Add the **nvme_core.multipath=N** option to the command line:

```
# grubby --update-kernel=ALL --args="nvme_core.multipath=N"
```

b. On the 64-bit IBM Z architecture, update the boot menu:

```
# zipl
```

c. Reboot the system.

- Using a kernel module configuration file:

a. Create the **/etc/modprobe.d/nvme_core.conf** configuration file with the following content:

```
options nvme_core multipath=N
```

b. Back up the **initramfs** file:

```
# cp /boot/initramfs-$(uname -r).img /boot/initramfs-$(uname -r).bak.$(date
+%m%d-%H%M%S).img
```

c. Rebuild the **initramfs**:

```
# cp /boot/initramfs-$(uname -r).img /boot/initramfs-$(uname -r).bak.$(date
+%m-%d-%H%M%S).img
# dracut --force --verbose
```

d. Reboot the system.

3. Enable DM Multipath:

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

4. Distribute I/O on all available paths. Add the following content in the **/etc/multipath.conf** file:

```
devices {
        device {
                vendor "NVME"
                product ".*"
                path_grouping_policy    group_by_prio
        }
}
```

NOTE

The **/sys/class/nvme-subsystem/nvme-subsys0/iopolicy** configuration file has no effect on the I/O distribution when DM Multipath manages the NVMe devices.

5. Reload the **multipathd** service to apply the configuration changes:

```
# multipath -r
```

Verification

- Verify if the native NVMe multipathing is disabled:

```
# cat /sys/module/nvme_core/parameters/multipath
N
```

- Verify if DM multipath recognizes the nvme devices:

```
# multipath -l

eui.00007a8962ab241100a0980000d851c8 dm-6 NVME,NetApp E-Series
size=20G features='0' hwhandler='0' wp=rw
`-+- policy='service-time 0' prio=0 status=active
  |- 0:10:2:2 nvme0n2 259:3 active undef running
`-+- policy='service-time 0' prio=0 status=enabled
  |- 4:11:2:2 nvme4n2 259:28 active undef running
`-+- policy='service-time 0' prio=0 status=enabled
  |- 5:32778:2:2 nvme5n2 259:38 active undef running
`-+- policy='service-time 0' prio=0 status=enabled
  |- 6:32779:2:2 nvme6n2 259:44 active undef running
```

Additional resources

- Configuring kernel command-line parameters
- Configuring DM Multipath

13.3. ENABLING NATIVE NVME MULTIPATHING

If native NVMe multipathing is disabled, you can enable it using the following solution.

Prerequisites

- The NVMe devices are connected to your system. For more information, see Overview of NVMe over fabric devices.

Procedure

1. Check if native NVMe multipathing is enabled in the kernel:

```
# cat /sys/module/nvme_core/parameters/multipath
```

   The command displays one of the following:

   N

   Native NVMe multipathing is disabled.

   Y

   Native NVMe multipathing is enabled.

2. If native NVMe multipathing is disabled, enable it by using one of the following methods:

   - Using a kernel option:

a. Remove the **nvme_core.multipath=N** option from the kernel command line:

```
# grubby --update-kernel=ALL --remove-args="nvme_core.multipath=N"
```

b. On the 64-bit IBM Z architecture, update the boot menu:

```
# zipl
```

c. Reboot the system.

- Using a kernel module configuration file:

a. Remove the **/etc/modprobe.d/nvme_core.conf** configuration file:

```
# rm /etc/modprobe.d/nvme_core.conf
```

b. Back up the **initramfs** file:

```
# cp /boot/initramfs-$(uname -r).img /boot/initramfs-$(uname -r).bak.$(date
+%m-%d-%H%M%S).img
```

c. Rebuild the **initramfs**:

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

d. Reboot the system.

3. Optional: On the running system, change the I/O policy on NVMe devices to distribute the I/O on all available paths:

```
# echo "round-robin" > /sys/class/nvme-subsystem/nvme-subsys0/iopolicy
```

4. Optional: Set the I/O policy persistently using **udev** rules. Create the **/etc/udev/rules.d/71-nvme-io-policy.rules** file with the following content:

```
ACTION=="add|change", SUBSYSTEM=="nvme-subsystem", ATTR{iopolicy}="round-robin"
```

Verification

1. Verify if your system recognizes the NVMe devices. The following example assumes you have a connected NVMe over fabrics storage subsystem with two NVMe namespaces:

```
# nvme list

Node             SN                   Model                                    Namespace Usage
Format           FW Rev
---------------- -------------------- ---------------------------------------- --------- -------------------------
- ---------------- --------
/dev/nvme0n1     a34c4f3a0d6f5cec     Linux                                    1         250.06  GB /
250.06  GB    512   B +  0 B   4.18.0-2
/dev/nvme0n2     a34c4f3a0d6f5cec     Linux                                    2         250.06  GB /
250.06  GB    512   B +  0 B   4.18.0-2
```

2. List all connected NVMe subsystems:

```
# nvme list-subsys

nvme-subsys0 - NQN=testnqn
\
 +- nvme0 fc traddr=nn-0x20000090fadd597a:pn-0x10000090fadd597a host_traddr=nn-0x20000090fac7e1dd:pn-0x10000090fac7e1dd live
 +- nvme1 fc traddr=nn-0x20000090fadd5979:pn-0x10000090fadd5979 host_traddr=nn-0x20000090fac7e1dd:pn-0x10000090fac7e1dd live
 +- nvme2 fc traddr=nn-0x20000090fadd5979:pn-0x10000090fadd5979 host_traddr=nn-0x20000090fac7e1de:pn-0x10000090fac7e1de live
 +- nvme3 fc traddr=nn-0x20000090fadd597a:pn-0x10000090fadd597a host_traddr=nn-0x20000090fac7e1de:pn-0x10000090fac7e1de live
```

Check the active transport type. For example, **nvme0 fc** indicates that the device is connected over the Fibre Channel transport, and **nvme tcp** indicates that the device is connected over TCP.

3. If you edited the kernel options, verify if native NVMe multipathing is enabled on the kernel command line:

```
# cat /proc/cmdline

BOOT_IMAGE=[...] nvme_core.multipath=Y
```

4. If you changed the I/O policy, verify if **round-robin** is the active I/O policy on NVMe devices:

```
# cat /sys/class/nvme-subsystem/nvme-subsys0/iopolicy

round-robin
```

Additional resources

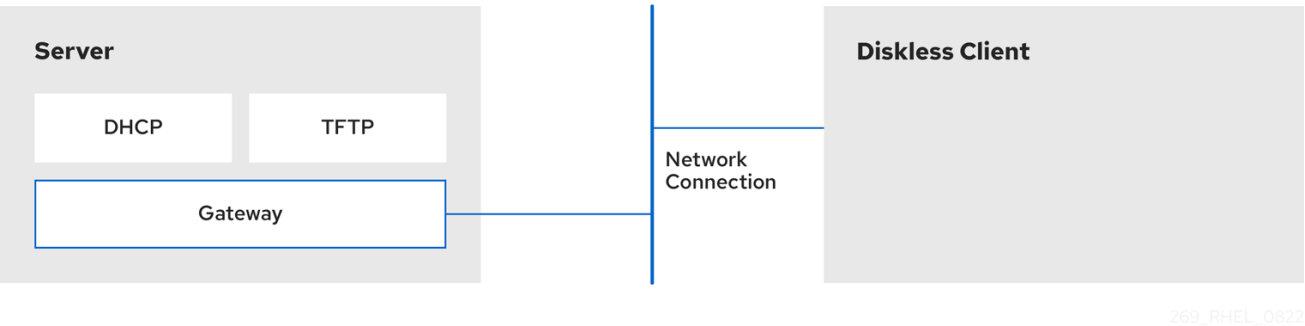
- Configuring kernel command-line parameters

CHAPTER 14. SETTING UP A REMOTE DISKLESS SYSTEM

In a network environment, you can set up multiple clients with the identical configuration by deploying a remote diskless system. By using the current Red Hat Enterprise Linux server version, you can save the cost of hard drives for these clients and configure the gateway on a separate server.

The following diagram describes the connection of a diskless client with the server through Dynamic Host Configuration Protocol (DHCP) and Trivial File Transfer Protocol (TFTP) services.

Figure 14.1. Remote diskless system settings diagram



14.1. PREPARING ENVIRONMENTS FOR THE REMOTE DISKLESS SYSTEM

Prepare your environment to continue with remote diskless system implementation. The remote diskless system booting requires the following services:

- Trivial File Transfer Protocol (TFTP) service, which is provided by tftp-server. The system uses the tftp service to retrieve the kernel image and the initial RAM disk, initrd, over the network, through the Preboot Execution Environment (PXE) loader.
- Dynamic Host Configuration Protocol (DHCP) service, which is provided by dhcp.

Prerequisites

- You have set up your network connection.

Procedure

1. Install the **dracut-network** package:

```
# dnf install dracut-network
```

2. Add the following line to the **/etc/dracut.conf.d/network.conf** file:

```
add_dracutmodules+=" nfs "
```

3. Ensure correct functionality of the remote diskless system in your environment by configuring services in the following order:

   a. Configure a TFTP service. For more information, see Configuring a TFTP service for diskless clients.

b. Configure a DHCP server. For more information, see Configuring a DHCP server for diskless clients.

c. Configure the Network File System (NFS) and an exported file system. For more information, see Configuring an exported file system for diskless clients .

14.2. CONFIGURING A TFTP SERVICE FOR DISKLESS CLIENTS

For the remote diskless system to function correctly in your environment, you need to first configure a Trivial File Transfer Protocol (TFTP) service for diskless clients.

> **NOTE**
>
> This configuration does not boot over the Unified Extensible Firmware Interface (UEFI). For UEFI based installation, see Configuring a TFTP server for UEFI-based clients .

Prerequisites

- You have installed the following packages:
  - **tftp-server**
  - **syslinux**

Procedure

1. Enable the **tftp** service:

```
# systemctl enable --now tftp
```

2. Create a **pxelinux** directory in the **tftp** root directory:

```
# mkdir -p /var/lib/tftpboot/pxelinux/
```

3. Copy the **/usr/share/syslinux/pxelinux.0** file to the **/var/lib/tftpboot/pxelinux/** directory:

```
# cp /usr/share/syslinux/pxelinux.0 /var/lib/tftpboot/pxelinux/
```

4. Copy **/usr/share/syslinux/ldlinux.c32** to **/var/lib/tftpboot/pxelinux/**:

```
# cp /usr/share/syslinux/ldlinux.c32 /var/lib/tftpboot/pxelinux/
```

5. Create a **pxelinux.cfg** directory in the **tftp** root directory:

```
# mkdir -p /var/lib/tftpboot/pxelinux/pxelinux.cfg/
```

Verification

- Check status of service **tftp**:

```
# systemctl status tftp
...
```

```
Active: active (running)
...
```

14.3. CONFIGURING A DHCP SERVER FOR DISKLESS CLIENTS

The remote diskless system requires several pre-installed services to enable correct functionality.

Prerequisites

- Install the Trivial File Transfer Protocol (TFTP) service.
- You have installed the following package:
  - **dhcp-server**
- You have configured the **tftp** service for diskless clients. For more information, see Configuring a TFTP service for diskless clients.

Procedure

1. Add the following configuration to the **/etc/dhcp/dhcpd.conf** file to setup a DHCP server and enable Preboot Execution Environment (PXE) for booting:

```
option space pxelinux;
option pxelinux.magic code 208 = string;
option pxelinux.configfile code 209 = text;
option pxelinux.pathprefix code 210 = text;
option pxelinux.reboottime code 211 = unsigned integer 32;
option architecture-type code 93 = unsigned integer 16;

subnet 192.168.205.0 netmask 255.255.255.0 {
  option routers 192.168.205.1;
  range 192.168.205.10 192.168.205.25;

  class "pxeclients" {
    match if substring (option vendor-class-identifier, 0, 9) = "PXEClient";
    next-server 192.168.205.1;

    if option architecture-type = 00:07 {
      filename "BOOTX64.efi";
      } else {
      filename "pxelinux/pxelinux.0";
    }
  }
}
```

   Your DHCP configuration might be different depending on your environment, like setting lease time or fixed address. For details, see Providing DHCP services.

NOTE

While using **libvirt** virtual machine as a diskless client, the **libvirt** daemon provides the DHCP service, and the standalone DHCP server is not used. In this situation, network booting must be enabled with the **bootp file=<filename>** option in the **libvirt** network configuration, **virsh net-edit**.

2. Enable **dhcpd.service**:

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

Verification

- Check the status of service **dhcpd.service**:

```
# systemctl status dhcpd.service
...
Active: active (running)
...
```

14.4. CONFIGURING AN EXPORTED FILE SYSTEM FOR DISKLESS CLIENTS

As a part of configuring a remote diskless system in your environment, you must configure an exported file system for diskless clients.

Prerequisites

- You have configured the **tftp** service for diskless clients. See section Configuring a TFTP service for diskless clients.
- You have configured the Dynamic Host Configuration Protocol (DHCP) server. See section Configuring a DHCP server for diskless clients .

Procedure

1. Configure the Network File System (NFS) server to export the root directory by adding it to the **/etc/exports** directory. For the complete set of instructions see Deploying an NFS server
2. Install a complete version of Red Hat Enterprise Linux to the root directory to accommodate completely diskless clients. To do that you can either install a new base system or clone an existing installation.
   - Install Red Hat Enterprise Linux to the exported location by replacing exported-root-directory with the path to the exported file system:

     ```
     # dnf install @Base kernel dracut-network nfs-utils --installroot=exported-root-directory --releasever=/
     ```

     By setting the **releasever** option to /, releasever is detected from the host (/) system.
   - Use the **rsync** utility to synchronize with a running system:

```
# rsync -a -e ssh --exclude='/proc/' --exclude='/sys/' example.com:/ exported-root-directory
```

- Replace *example.com* with the hostname of the running system with which to synchronize via the **rsync** utility.
- Replace *exported-root-directory* with the path to the exported file system.
  Note, that for this option you must have a separate existing running system, which you will clone to the server by the command above.

3. Configure the file system, which is ready for export, before you can use it with diskless clients:

   a. Copy the diskless client supported kernel (**vmlinuz-_kernel-version_pass:attributes**) to the **tftp** boot directory:

   ```
   # cp /exported-root-directory/boot/vmlinuz-kernel-version /var/lib/tftpboot/pxelinux/
   ```

   b. Create the **initramfs-*kernel-version*.img** file locally and move it to the exported root directory with NFS support:

   ```
   # dracut --add nfs initramfs-kernel-version.img kernel-version
   ```

   For example:

   ```
   # dracut --add nfs /exports/root/boot/initramfs-5.14.0-202.el9.x86_64.img 5.14.0-202.el9.x86_64
   ```

   Example for creating initrd, using current running kernel version, and overwriting existing image:

   ```
   # dracut -f --add nfs "boot/initramfs-$(uname -r).img" "$(uname -r)"
   ```

   c. Change the file permissions for **initrd** to **0644**:

   ```
   # chmod 0644 /exported-root-directory/boot/initramfs-kernel-version.img
   ```

   WARNING

   If you do not change the **initrd** file permissions, the **pxelinux.0** boot loader fails with a "file not found" error.

   d. Copy the resulting **initramfs-*kernel-version*.img** file into the **tftp** boot directory:

   ```
   # cp /exported-root-directory/boot/initramfs-kernel-version.img /var/lib/tftpboot/pxelinux/
   ```

e. Add the following configuration in the **/var/lib/tftpboot/pxelinux/pxelinux.cfg/default** file to edit the default boot configuration for using the **initrd** and the kernel:

```
default rhel9

label rhel9
  kernel vmlinuz-kernel-version
  append initrd=initramfs-kernel-version.img root=nfs:_server-ip_:/exported-root-directory
rw
```

This configuration instructs the diskless client root to mount the **/exported-root-directory** exported file system in a read/write format.

f. Optional: Mount the file system in a **read-only`** format by editing the **/var/lib/tftpboot/pxelinux/pxelinux.cfg/default** file with the following configuration:

```
default rhel9

label rhel9
  kernel vmlinuz-kernel-version
  append initrd=initramfs-kernel-version.img root=nfs:server-ip:/exported-root-directory ro
```

g. Restart the NFS server:

```
# systemctl restart nfs-server.service
```

You can now export the NFS share to diskless clients. These clients can boot over the network via Preboot Execution Environment (PXE).

14.5. RE-CONFIGURING A REMOTE DISKLESS SYSTEM

If you want to install packages, restart services, or debug the issues, you can reconfigure the system.

Prerequisites

- You have enabled the **no_root_squash** option in the exported file system.

Procedure

- Change the user password:
  - Change the command line to */exported/root/directory*:

    ```
    # chroot /exported/root/directory /bin/bash
    ```

  - Change the password for the user you want:

    ```
    # passwd <username>
    ```

    Replace the *<username>* with a real user for whom you want to change the password.

  - Exit the command line.
- Install software on a remote diskless system:

```
# dnf install <package> --installroot=/exported/root/directory --releasever=/ --config
/etc/dnf/dnf.conf --setopt=reposdir=/etc/yum.repos.d/
```

Replace *<package>* with the actual package you want to install.

- Configure two separate exports to split a remote diskless system into a **/usr** and a **/var**. For more information, see Deploying an NFS server.

14.6. TROUBLESHOOTING COMMON ISSUES WITH LOADING A REMOTE DISKLESS SYSTEM

Based on the earlier configuration, some issues can occur while loading the remote diskless system. Following are some examples of the most common issues and ways to troubleshoot them on a Red Hat Enterprise Linux server.

Example 14.1. The client does not get an IP address

1. Check if the Dynamic Host Configuration Protocol (DHCP) service is enabled on the server.
   a. Check if the **dhcp.service** is running:

      ```
      # systemctl status dhcpd.service
      ```

   b. If the **dhcp.service** is inactive, enable and start it:

      ```
      # systemctl enable dhcpd.service
      # systemctl start dhcpd.service
      ```

   c. Reboot the diskless client.
   d. Check the DHCP configuration file **/etc/dhcp/dhcpd.conf**. For details, see Configuring a DHCP server for diskless clients.
2. Check if the Firewall ports are opened.
   a. Check if the **dhcp.service** is listed in active services:

      ```
      # firewall-cmd --get-active-zones
      # firewall-cmd --info-zone=public
      ```

   b. If the **dhcp.service** is not listed in active services, add it to the list:

      ```
      # firewall-cmd --add-service=dhcp --permanent
      ```

   c. Check if the **nfs.service** is listed in active services:

      ```
      # firewall-cmd --get-active-zones
      # firewall-cmd --info-zone=public
      ```

   d. If the **nfs.service** is not listed in active services, add it to the list:

      ```
      # firewall-cmd --add-service=nfs --permanent
      ```

Example 14.2. The file is not available during the booting a remote diskless system

1. Check if the file is in the **/var/lib/tftpboot/** directory.
2. If the file is in the directory, ensure if it has the following permissions:

```
# chmod 644 pxelinux.0
```

3. Check if the Firewall ports are opened.

Example 14.3. System boot failed after loading kernel/initrd

1. Check if the NFS service is enabled on a server.
   a. Check if **nfs.service** is running:

```
# systemctl status nfs.service
```

   b. If the **nfs.service** is inactive, you must start and enable it:

```
# systemctl start nfs.service
# systemctl enable nfs.service
```

2. Check if the parameters are correct in the **/var/lib/tftpboot/pxelinux.cfg/** directory. For details, see Configuring an exported file system for diskless clients .
3. Check if the Firewall ports are opened.

CHAPTER 15. GETTING STARTED WITH SWAP

Use the swap space to provide temporary storage for inactive processes and data, and prevent out-of-memory errors when physical memory is full. The swap space acts as an extension to the physical memory and allows the system to continue running smoothly even when physical memory is exhausted. Note that using swap space can slow down system performance, so optimizing the use of physical memory, before relying on swap space, can be more favorable.

15.1. OVERVIEW OF SWAP SPACE

Swap space in Linux is used when the amount of physical memory (RAM) is full. If the system needs more memory resources and the RAM is full, inactive pages in memory are moved to the swap space. While swap space can help machines with a small amount of RAM, it should not be considered a replacement for more RAM.

Swap space is located on hard drives, which have a slower access time than physical memory. Swap space can be a dedicated swap partition (recommended), a swap file, or a combination of swap partitions and swap files.

In years past, the recommended amount of swap space increased linearly with the amount of RAM in the system. However, modern systems often include hundreds of gigabytes of RAM. As a consequence, recommended swap space is considered a function of system memory workload, not system memory.

15.2. RECOMMENDED SYSTEM SWAP SPACE

The appropriate size of a swap partition ultimately depends on the system memory workload, not system memory alone. However, the following table provides the recommended minimum guidelines for swap partition size based on the amount of RAM in your system, which are typically set automatically during installation.

The swap partition size is set automatically during installation. To allow for hibernation, however, you need to edit the swap space in the custom partitioning stage.

The following guidelines are especially important on systems with low memory, such as 1 GB or less. Failure to allocate sufficient swap space on these systems can cause issues, such as instability or even render the installed system unbootable.

Table 15.1. Recommended swap space

Amount of RAM in the system	Recommended swap space	Recommended swap space if allowing for hibernation
Less than 2 GiB	2 times the amount of RAM	3 times the amount of RAM
2 GB - 8 GB	Equal to the amount of RAM	2 times the amount of RAM
8 GB - 64 GB	At least 4 GB	1.5 times the amount of RAM
More than 64 GiB	Workload dependent (at least 4GiB)	Hibernation not recommended

Distributing swap space over multiple storage devices improves swap space performance, particularly on systems with fast drives, controllers, and interfaces.

IMPORTANT

File systems and LVM2 volumes assigned as swap space *should not* be in use when being modified. Any attempts to modify swap fail if a system process or the kernel is using swap space. Use the **free** and **cat /proc/swaps** commands to verify how much and where swap is in use.

Resizing swap space requires temporarily removing it from the system, which is done by disabling the swap volume of the file by using the **swapoff** command. This can be problematic if running applications rely on the additional swap space and might run into low-memory situations.

If you encounter difficulties disabling swap due to high memory pressure or locked pages, alternatively, perform swap resizing from rescue mode. see Debug boot options. When prompted to mount the file system, select **Skip**.

15.3. CREATING AN LVM2 LOGICAL VOLUME FOR SWAP

You can create an LVM2 logical volume for swap. Assuming */dev/VolGroup00/LogVol02* is the swap volume you want to add.

Prerequisites

- You have enough disk space.

Procedure

1. Create the LVM2 logical volume of size *2 GB*:

```
# lvcreate VolGroup00 -n LogVol02 -L 2G
```

2. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol02
```

3. Add the following entry to the **/etc/fstab** file:

```
/dev/VolGroup00/LogVol02 none swap defaults 0 0
```

4. Regenerate mount units so that your system registers the new configuration:

```
# systemctl daemon-reload
```

5. Activate swap on the logical volume:

```
# swapon -v /dev/VolGroup00/LogVol02
```

Verification

- To test if the swap logical volume was successfully created and activated, inspect active swap space by using the following command:

```
# cat /proc/swaps
              total       used       free      shared  buff/cache   available
Mem:           30Gi       1.2Gi       28Gi       12Mi       994Mi       28Gi
Swap:          22Gi          0B       22Gi
```

```
# free -h
              total       used       free      shared  buff/cache   available
Mem:           30Gi       1.2Gi       28Gi       12Mi       995Mi       28Gi
Swap:          17Gi          0B       17Gi
```

15.4. CREATING AND MANAGING A STANDARD SWAP PARTITION

Use a standard swap partition for swap space. You can use standard partitioning tools like **fdisk** or **parted** to create a dedicated partition.

Prerequisites

- You have enough unallocated disk space on a drive.
- You have the name of the disk device, for example, /**dev**/**sda**).

Procedure

1. Start the partitioning tool for your disk, for example, /**dev**/**sda**:

```
$ fdisk /dev/sda
```

2. Create a new partition of the desired size and set its type to **Linux swap**:

> **NOTE**
>
> For **fdisk**, use the 't' command to change the partition type, entering the hex code **82** for Linux swap.

3. Write the changes and exit the utility.
4. Format the new swap partition (assuming the new partition is /**dev**/**sda4**):

```
# mkswap /dev/sda4
```

5. Add an entry to the /**etc**/**fstab** file to enable the swap partition at boot time:

```
# /dev/sda4 none swap defaults 0 0
```

6. Regenerate mount units to register the new configuration:

```
# systemctl daemon-reload
```

7. Activate the swap partition immediately:

```
# swapon -v /dev/sda4
```

Verification

- To confirm the swap partition was created and activated, inspect the active swap space:

```
# cat /proc/swaps
# free -h
```

15.5. CREATING A SWAP FILE

Set up a swap file to provide virtual memory that prevents system crashes when physical RAM becomes full. This solution is particularly useful when you need additional swap space without repartitioning disks or modifying existing storage configurations.

Prerequisites

- You have enough disk space.

Procedure

1. Determine the size of the new swap file in megabytes and multiply by 1024 to determine the number of blocks. For example, the block size of a 64 MB swap file is 65536.

2. Create an empty file:

```
# dd if=/dev/zero of=/swapfile bs=1024 count=65536
```

Replace *65536* with the value equal to the required block size.

NOTE

On modern filesystems such as ext4 or XFS, **fallocate** is preferable instead of **dd**. This method is faster and avoids unnecessary disk I/O.

3. Set up the swap file with the command:

```
# mkswap /swapfile
```

4. Change the security of the swap file so it is not world readable.

```
# chmod 0600 /swapfile
```

5. Edit the **/etc/fstab** file with the following entries to enable the swap file at boot time:

```
/swapfile none swap defaults 0 0
```

The next time the system boots, it activates the new swap file.

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

```
# systemctl daemon-reload
```

7. Activate the swap file immediately:

```
# swapon /swapfile
```

Verification

- To test if the new swap file was successfully created and activated, inspect active swap space by using the following command:

```
$ cat /proc/swaps
```

```
$ free -h
```

15.6. CREATING A SWAP VOLUME BY USING THE STORAGE RHEL SYSTEM ROLE

You can use the **storage** RHEL system role to create or modify swap volumes on block devices.

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: Create a disk device with swap
  hosts: managed-node-01.example.com
  roles:
    - rhel-system-roles.storage
  vars:
    storage_volumes:
      - name: swap_fs
        type: disk
        disks:
          - /dev/sdb
        size: 15 GiB
        fs_type: swap
```

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

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
```

15.7. EXTENDING SWAP ON AN LVM2 LOGICAL VOLUME

You can extend swap space on an existing LVM2 logical volume. Assuming */dev/VolGroup00/LogVol01* is the volume you want to extend by *2 GB*.

Prerequisites

- You have enough disk space.

Procedure

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol01
```

2. Resize the LVM2 logical volume by *2 GB*:

```
# lvresize /dev/VolGroup00/LogVol01 -L +2G
```

3. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol01
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol01
```

Verification

- To test if the swap logical volume was successfully extended and activated, inspect active swap space:

```
# cat /proc/swaps
Filename                Type        Size        Used        Priority
/dev/dm-1               partition   16322556    0           -2
/dev/dm-4               partition   7340028     0           -3
```

```
# free -h
              total        used        free      shared  buff/cache   available
Mem:           30Gi       1.2Gi        28Gi        12Mi       994Mi        28Gi
Swap:          22Gi          0B        22Gi
```

15.8. REDUCING SWAP ON AN LVM2 LOGICAL VOLUME

You can reduce swap on an LVM2 logical volume. Assuming */dev/VolGroup00/LogVol01* is the volume you want to reduce.

Procedure

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol01
```

2. Clean the swap signature:

```
# wipefs -a /dev/VolGroup00/LogVol01
```

3. Reduce the LVM2 logical volume by 512 MB:

```
# lvreduce /dev/VolGroup00/LogVol01 -L -512M
```

4. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol01
```

5. Activate swap on the logical volume:

```
# swapon -v /dev/VolGroup00/LogVol01
```

Verification

- To test if the swap logical volume was successfully reduced, inspect active swap space by using the following command:

```
$ cat /proc/swaps
```

```
$ free -h
```

15.9. REMOVING AN LVM2 LOGICAL VOLUME FOR SWAP

You can remove an LVM2 logical volume for swap. Assuming */dev/VolGroup00/LogVol02* is the swap volume you want to remove.

Procedure

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol02
```

2. Remove the LVM2 logical volume:

```
# lvremove /dev/VolGroup00/LogVol02
```

3. Remove the following associated entry from the **/etc/fstab** file:

```
/dev/VolGroup00/LogVol02 none swap defaults 0 0
```

4. Regenerate mount units to register the new configuration:

```
# systemctl daemon-reload
```

Verification

- Test if the logical volume was successfully removed, inspect active swap space by using the following command:

```
$ cat /proc/swaps
```

```
$ free -h
```

15.10. REMOVING A SWAP FILE

You can remove a swap file.

Procedure

1. Disable the **/swapfile** swap file:

```
# swapoff -v /swapfile
```

2. Remove its entry from the **/etc/fstab** file accordingly.

3. Regenerate mount units so that your system registers the new configuration:

```
# systemctl daemon-reload
```

4. Remove the actual file:

```
# rm /swapfile
```

15.11. ADJUSTING VIRTUAL MEMORY (VM) TUNABLES

Virtual Memory (VM) tunables are kernel parameters that control how the system manages memory, including how aggressively it uses swap space. Adjusting these settings can significantly impact system performance based on the workload.

The **vm.swappiness** parameter controls the kernel's tendency to move processes out of physical memory and into swap space. The value is a percentage, ranging from 0 to 100:

- **Higher Value (e.g., 60 or 100):** The kernel will swap processes to disk more aggressively. This can free up physical memory for other uses (like the file system cache), but it may increase I/O operations and latency if swapped processes are frequently needed.

- **Lower Value (e.g., 0 or 10):** The kernel will try to avoid swapping and keep processes in physical memory for as long as possible. This is generally preferred for desktop systems or servers with fast I/O and large amounts of RAM.

Following other relevant VM tunables can influence swap behavior:

- **vm.dirty_ratio**: The percentage of system memory that can be filled with "dirty" pages (memory pages that have been modified but not yet written to disk) before the kernel begins actively writing them out.
- **vm.dirty_background_ratio**: The percentage of system memory that can be filled with dirty pages before a background kernel process begins writing them out. This is a less aggressive action than **vm.dirty_ratio**.

Procedure

1. View the current value:

```
$ cat /proc/sys/vm/swappiness
```

   The default value is 60.

2. Set the value temporarily, for example, to 10:

```
# sysctl vm.swappiness=10
```

3. Set the value permanently to persist across reboots by editing the **/etc/sysctl.d/99-sysctl.conf** or a similar configuration file:

```
vm.swappiness = 10
```

4. Apply the changes:

```
# sysctl -p
```

CHAPTER 16. CONFIGURING FIBRE CHANNEL OVER ETHERNET

Based on the IEEE T11 FC-BB-5 standard, Fibre Channel over Ethernet (FCoE) is a protocol to transmit Fibre Channel frames over Ethernet networks. Typically, data centers have a dedicated LAN and Storage Area Network (SAN) that are separated from each other with their own specific configuration. FCoE combines these networks into a single and converged network structure. Benefits of FCoE are, for example, lower hardware and energy costs.

16.1. USING HARDWARE FCOE HBAS IN RHEL

In RHEL you can use hardware Fibre Channel over Ethernet (FCoE) Host Bus Adapter (HBA), which is supported by the following drivers:

- **qedf**
- **bnx2fc**
- **fnic**

If you use such a HBA, you configure the FCoE settings in the setup of the HBA. For more information, see the documentation of the adapter.

After you configure the HBA, the exported Logical Unit Numbers (LUN) from the Storage Area Network (SAN) are automatically available to RHEL as **/dev/sd*** devices. You can use these devices similar to local storage devices.

16.2. SETTING UP AN FCOE DEVICE

After you complete this procedure, the exported LUNs from the Storage Area Network (SAN) are automatically available to RHEL as **/dev/sd*** devices. You can use these devices in a similar way to local storage devices.

Prerequisites

- You have configured the network switch to support VLAN.
- The SAN uses a VLAN to separate the storage traffic from normal Ethernet traffic.
- You have configured the HBA of the server in its BIOS.
- The HBA is connected to the network and the link is up. For more information, see the documentation of your HBA.

Procedure

1. Install the **fcoe-utils** package:

```
# dnf install fcoe-utils
```

2. Copy the **/etc/fcoe/cfg-ethx** template file to **/etc/fcoe/cfg-*interface_name***. For example, if you want to configure the **enp1s0** interface to use FCoE, enter the following command:

```
# cp /etc/fcoe/cfg-ethx /etc/fcoe/cfg-enp1s0
```

3. Enable and start the **fcoe** service:

```
# systemctl enable --now fcoe
```

4. Discover the FCoE VLAN on interface **enp1s0**, create a network device for the discovered VLAN, and start the initiator:

```
# fipvlan -s -c enp1s0
Created VLAN device enp1s0.200
Starting FCoE on interface enp1s0.200
Fibre Channel Forwarders Discovered
interface       | VLAN | FCF MAC
------------------------------------------
enp1s0          | 200  | 00:53:00:a7:e7:1b
```

5. Optional: Display details about the discovered targets, the LUNs, and the devices associated with the LUNs:

```
# fcoeadm -t
Interface:        enp1s0.200
Roles:            FCP Target
Node Name:        0x500a0980824acd15
Port Name:        0x500a0982824acd15
Target ID:        0
MaxFrameSize:     2048 bytes
OS Device Name:   rport-11:0-1
FC-ID (Port ID):  0xba00a0
State:            Online

LUN ID  Device Name   Capacity   Block Size  Description
------  -----------  ----------  ----------  ---------------------
     0  sdb           28.38 GiB      512     NETAPP LUN (rev 820a)
     ...
```

This example shows that LUN 0 from the SAN has been attached to the host as the **/dev/sdb** device.

Verification

- Display information about all active FCoE interfaces:

```
# fcoeadm -i
Description:      BCM57840 NetXtreme II 10 Gigabit Ethernet
Revision:         11
Manufacturer:     Broadcom Inc. and subsidiaries
Serial Number:    000AG703A9B7

Driver:           bnx2x Unknown
Number of Ports:  1

    Symbolic Name:     bnx2fc (QLogic BCM57840) v2.12.13 over enp1s0.200
    OS Device Name:    host11
```

```
Node Name:        0x2000000af70ae935
Port Name:        0x2001000af70ae935
Fabric Name:      0x20c8002a6aa7e701
Speed:            10 Gbit
Supported Speed:  1 Gbit, 10 Gbit
MaxFrameSize:     2048 bytes
FC-ID (Port ID):  0xba02c0
State:            Online
```

Additional resources

- **fcoeadm(8)** man page on your system
- **/usr/share/doc/fcoe-utils/README**
- Using Fibre Channel devices

CHAPTER 17. MANAGING TAPE DEVICES

A tape device is a magnetic tape where data is stored and accessed sequentially. Data is written to this tape device with the help of a tape drive. There is no need to create a file system in order to store data on a tape device. Tape drives can be connected to a host computer with various interfaces like, SCSI, FC, USB, SATA, and other interfaces.

17.1. TYPES OF TAPE DEVICES

The following is a list of the different types of tape devices:

- **/dev/st0** is a rewinding tape device.
- **/dev/nst0** is a non-rewinding tape device. Use non-rewinding devices for daily backups.

There are several advantages to using tape devices. They are cost efficient and stable. Tape devices are also resilient against data corruption and are suitable for data retention.

17.2. INSTALLING TAPE DRIVE MANAGEMENT TOOL

Install the **mt-st** package for tape drive operations. Use the **mt** utility to control magnetic tape drive operations, and the **st** utility for SCSI tape driver.

Procedure

- Install the **mt-st** package:

```
# dnf install mt-st
```

Additional resources

- **mt(1)** and **st(4)** man pages on your system

17.3. TAPE COMMANDS

The following are the common **mt** commands:

Table 17.1. mt commands

Command	Description
mt -f /dev/*st0* status	Displays the status of the tape device.
mt -f /dev/*st0* erase	Erases the entire tape.
mt -f /dev/*nst0* rewind	Rewinds the tape device.
mt -f /dev/*nst0* fsf *n*	Switches the tape head to the forward record. Here, *n* is an optional file count. If a file count is specified, tape head skips *n* records.

Command	Description
mt -f /dev/*nst0* bsfm *n*	Switches the tape head to the previous record.
mt -f /dev/*nst0* eod	Switches the tape head to the end of the data.

17.4. WRITING TO REWINDING TAPE DEVICES

A rewind tape device rewinds the tape after every operation. To back up data, you can use the **tar** command. By default, in tape devices the **block size** is 10KB (**bs=10k**). You can set the **TAPE** environment variable using the **export TAPE=*/dev/st0*** attribute. Use the **-f** device option instead, to specify the tape device file. This option is useful when you use more than one tape device.

Prerequisites

1. You have installed the **mt-st** package. For more information, see Installing tape drive management tool.
2. Load the tape drive:

```
# mt -f /dev/st0 load
```

Procedure

1. Check the tape head:

```
# mt -f /dev/st0 status

SCSI 2 tape drive:
File number=-1, block number=-1, partition=0.
Tape block size 0 bytes. Density code 0x0 (default).
Soft error count since last status=0
General status bits on (50000):
 DR_OPEN IM_REP_EN
```

Here:

- the current **file number** is -1.
- the **block number** defines the tape head. By default, it is set to -1.
- the **block size** 0 indicates that the tape device does not have a fixed block size.
- the **Soft error count** indicates the number of encountered errors after executing the mt status command.
- the **General status bits** explains the stats of the tape device.
- **DR_OPEN** indicates that the door is open and the tape device is empty. **IM_REP_EN** is the immediate report mode.

2. If the tape device is not empty, overwrite it:

```
# tar -czf /dev/st0 _/source/directory
```

This command overwrites the data on a tape device with the content of ***/source/directory***.

3. Back up the ***/source/directory*** to the tape device:

```
# tar -czf /dev/st0 _/source/directory
tar: Removing leading `/' from member names
/source/directory
/source/directory/man_db.conf
/source/directory/DIR_COLORS
/source/directory/rsyslog.conf
[...]
```

4. View the status of the tape device:

```
# mt -f /dev/st0 status
```

Verification

- View the list of all files on the tape device:

```
# tar -tzf /dev/st0
/source/directory/
/source/directory/man_db.conf
/source/directory/DIR_COLORS
/source/directory/rsyslog.conf
[...]
```

Additional resources

- **mt(1)**, **st(4)**, and **tar(1)** man pages on your system
- Tape drive media detected as write protected (Red Hat Knowledgebase)
- How to check if tape drives are detected in the system (Red Hat Knowledgebase)

17.5. WRITING TO NON-REWINDING TAPE DEVICES

A non-rewinding tape device leaves the tape in its current status, after completing the execution of a certain command. For example, after a backup, you could append more data to a non-rewinding tape device. You can also use it to avoid any unexpected rewinds.

Prerequisites

1. You have installed the **mt-st** package. For more information, see Installing tape drive management tool.
2. Load the tape drive:

```
# mt -f /dev/nst0 load
```

Procedure

1. Check the tape head of the non-rewinding tape device **/dev/nst0**:

```
# mt -f /dev/nst0 status
```

2. Specify the pointer at the head or at the end of the tape:

```
# mt -f /dev/nst0 rewind
```

3. Append the data on the tape device:

```
# mt -f /dev/nst0 eod
# tar -czf /dev/nst0 /source/directory/
```

4. Back up the ***/source/directory/*** to the tape device:

```
# tar -czf /dev/nst0 /source/directory/
tar: Removing leading `/' from member names
/source/directory/
/source/directory/man_db.conf
/source/directory/DIR_COLORS
/source/directory/rsyslog.conf
[...]
```

5. View the status of the tape device:

```
# mt -f /dev/nst0 status
```

Verification

- View the list of all files on the tape device:

```
# tar -tzf /dev/nst0
/source/directory/
/source/directory/man_db.conf
/source/directory/DIR_COLORS
/source/directory/rsyslog.conf
[...]
```

Additional resources

- **mt(1)**, **st(4)**, and **tar(1)** man pages on your system
- Tape drive media detected as write protected (Red Hat Knowledgebase)
- How to check if tape drives are detected in the system (Red Hat Knowledgebase)

17.6. SWITCHING TAPE HEAD IN TAPE DEVICES

You can switch the tape head in the tape device by using the **eod** option.

Prerequisites

1. You have installed the **mt-st** package. For more information, see Installing tape drive management tool.
2. Data is written to the tape device. Fore more information, see Writing to rewinding tape devices or Writing to non-rewinding tape devices.

Procedure

- To view the current position of the tape pointer:

```
# mt -f /dev/nst0 tell
```

- To switch the tape head, while appending the data to the tape devices:

```
# mt -f /dev/nst0 eod
```

- To go to the previous record:

```
# mt -f /dev/nst0 bsfm 1
```

- To go to the forward record:

```
# mt -f /dev/nst0 fsf 1
```

Additional resources

- **mt(1)** man page on your system

17.7. RESTORING DATA FROM TAPE DEVICES

You can restore data from a tape device by using the **tar** command.

Prerequisites

1. You have installed the **mt-st** package. For more information, see Installing tape drive management tool.
2. Data is written to the tape device. For more information, see Writing to rewinding tape devices or Writing to non-rewinding tape devices.

Procedure

- For rewinding tape devices **/dev/st0**:
  - Restore the ***/source/directory/***:

```
# tar -xzf /dev/st0 /source/directory/
```

- For non-rewinding tape devices **/dev/nst0**:
  - Rewind the tape device:

```
# mt -f /dev/nst0 rewind
```

- Restore the **etc** directory:

```
# tar -xzf /dev/nst0 /source/directory/
```

Additional resources

- **mt(1)** and **tar(1)** man pages on your system

17.8. ERASING DATA FROM TAPE DEVICES

You can erase data from a tape device by using the **erase** option.

Prerequisites

1. You have installed the **mt-st** package. For more information, see Installing tape drive management tool.
2. Data is written to the tape device. For more information, see Writing to rewinding tape devices or Writing to non-rewinding tape devices.

Procedure

1. Erase data from the tape device:

```
# mt -f /dev/st0 erase
```

2. Unload the tape device:

```
# mt -f /dev/st0 offline
```

Additional resources

- **mt(1)** man page on your system

CHAPTER 18. MANAGING RAID

You can use a Redundant Array of Independent Disks (RAID) to store data across multiple drives. It can help to avoid data loss if a drive has failed.

18.1. OVERVIEW OF RAID

In a RAID, multiple devices, such as HDD, SSD, or NVMe are combined into an array to accomplish performance or redundancy goals not achievable with one large and expensive drive. This array of devices appears to the computer as a single logical storage unit or drive.

RAID supports various configurations, including levels 0, 1, 4, 5, 6, 10, and linear. RAID uses techniques such as disk striping (RAID Level 0), disk mirroring (RAID Level 1), and disk striping with parity (RAID Levels 4, 5 and 6) to achieve redundancy, lower latency, increased bandwidth, and maximized ability to recover from hard disk crashes.

RAID distributes data across each device in the array by breaking it down into consistently-sized chunks, commonly 256 KB or 512 KB, although other values are acceptable. It writes these chunks to a hard drive in the RAID array according to the RAID level employed. While reading the data, the process is reversed, giving the illusion that the multiple devices in the array are actually one large drive.

RAID technology is beneficial for those who manage large amounts of data. The following are the primary reasons to deploy RAID:

- It enhances speed
- It increases storage capacity using a single virtual disk
- It minimizes data loss from disk failure
- The RAID layout and level online conversion

18.2. RAID TYPES

The following are the possible types of RAID:

Firmware RAID

Firmware RAID, also known as ATARAID, is a type of software RAID where the RAID sets can be configured using a firmware-based menu. The firmware used by this type of RAID also hooks into the BIOS, allowing you to boot from its RAID sets. Different vendors use different on-disk metadata formats to mark the RAID set members. The Intel Matrix RAID is an example of a firmware RAID system.

Hardware RAID

A hardware-based array manages the RAID subsystem independently from the host. It might present multiple devices per RAID array to the host.
Hardware RAID devices might be internal or external to the system. Internal devices commonly consists of a specialized controller card that handles the RAID tasks transparently to the operating system. External devices commonly connect to the system via SCSI, Fibre Channel, iSCSI, InfiniBand, or other high speed network interconnect and present volumes such as logical units to the system.

RAID controller cards function like a SCSI controller to the operating system and handle all the actual drive communications. You can plug the drives into the RAID controller similar to a normal SCSI controller and then add them to the RAID controller's configuration. The operating system will not be able to tell the difference.

Software RAID

A software RAID implements the various RAID levels in the kernel block device code. It offers the cheapest possible solution because expensive disk controller cards or hot-swap chassis are not required. With hot-swap chassis, you can remove a hard drive without powering off your system. Software RAID also works with any block storage, which are supported by the Linux kernel, such as SATA, SCSI, and NVMe. With today's faster CPUs, Software RAID also generally outperforms hardware RAID, unless you use high-end storage devices.
Since the Linux kernel contains a multiple device (MD) driver, the RAID solution becomes completely hardware independent. The performance of a software-based array depends on the server CPU performance and load.

The following are the key features of the Linux software RAID stack:

- Multithreaded design
- Portability of arrays between Linux machines without reconstruction
- Backgrounded array reconstruction using idle system resources
- Hot-swap drive support
- Automatic CPU detection to take advantage of certain CPU features such as streaming Single Instruction Multiple Data (SIMD) support.
- Automatic correction of bad sectors on disks in an array.
- Regular consistency checks of RAID data to ensure the health of the array.
- Proactive monitoring of arrays with email alerts sent to a designated email address on important events.
- Write-intent bitmaps, which drastically increase the speed of resync events by allowing the kernel to know precisely which portions of a disk need to be resynced instead of having to resync the entire array after a system crash.

  NOTE

  The resync is a process to synchronize the data over the devices in the existing RAID to achieve redundancy.

- Resync checkpointing so that if you reboot your computer during a resync, at startup the resync resumes where it left off and not starts all over again.
- The ability to change parameters of the array after installation, which is called reshaping. For example, you can grow a 4-disk RAID5 array to a 5-disk RAID5 array when you have a new device to add. This grow operation is done live and does not require you to reinstall on the new array.
- Reshaping supports changing the number of devices, the RAID algorithm or size of the RAID array type, such as RAID4, RAID5, RAID6, or RAID10.
- Takeover supports RAID level conversion, such as RAID0 to RAID6.
- Cluster MD, which is a storage solution for a cluster, provides the redundancy of RAID1 mirroring to the cluster. Currently, only RAID1 is supported.

18.3. RAID LEVELS AND LINEAR SUPPORT

The following are the supported configurations by RAID, including levels 0, 1, 4, 5, 6, 10, and linear:

Level 0

RAID level 0, often called striping, is a performance-oriented striped data mapping technique. This means the data being written to the array is broken down into stripes and written across the member disks of the array, allowing high I/O performance at low inherent cost but provides no redundancy. RAID level 0 implementations only stripe the data across the member devices up to the size of the smallest device in the array. This means that if you have multiple devices with slightly different sizes, each device gets treated as though it was the same size as the smallest drive. Therefore, the common storage capacity of a level 0 array is the total capacity of all disks. If the member disks have a different size, then the RAID0 uses all the space of those disks using the available zones.

Level 1

RAID level 1, or mirroring, provides redundancy by writing identical data to each member disk of the array, leaving a mirrored copy on each disk. Mirroring remains popular due to its simplicity and high level of data availability. Level 1 operates with two or more disks, and provides very good data reliability and improves performance for read-intensive applications but at relatively high costs. RAID level 1 is costly because you write the same information to all of the disks in the array, which provides data reliability, but in a much less space-efficient manner than parity based RAID levels such as level 5. However, this space inefficiency comes with a performance benefit, which is parity-based RAID levels that consume considerably more CPU power in order to generate the parity while RAID level 1 simply writes the same data more than once to the multiple RAID members with very little CPU overhead. As such, RAID level 1 can outperform the parity-based RAID levels on machines where software RAID is employed and CPU resources on the machine are consistently taxed with operations other than RAID activities.

The storage capacity of the level 1 array is equal to the capacity of the smallest mirrored hard disk in a hardware RAID or the smallest mirrored partition in a software RAID. Level 1 redundancy is the highest possible among all RAID types, with the array being able to operate with only a single disk present.

Level 4

Level 4 uses parity concentrated on a single disk drive to protect data. Parity information is calculated based on the content of the rest of the member disks in the array. This information can then be used to reconstruct data when one disk in the array fails. The reconstructed data can then be used to satisfy I/O requests to the failed disk before it is replaced and to repopulate the failed disk after it has been replaced.
Since the dedicated parity disk represents an inherent bottleneck on all write transactions to the RAID array, level 4 is seldom used without accompanying technologies such as write-back caching. Or it is used in specific circumstances where the system administrator is intentionally designing the software RAID device with this bottleneck in mind such as an array that has little to no write transactions once the array is populated with data. RAID level 4 is so rarely used that it is not available as an option in Anaconda. However, it could be created manually by the user if needed.

The storage capacity of hardware RAID level 4 is equal to the capacity of the smallest member partition multiplied by the number of partitions minus one. The performance of a RAID level 4 array is always asymmetrical, which means reads outperform writes. This is because write operations consume extra CPU resources and main memory bandwidth when generating parity, and then also consume extra bus bandwidth when writing the actual data to disks because you are not only writing the data, but also the parity. Read operations need only read the data and not the parity unless the array is in a degraded state. As a result, read operations generate less traffic to the drives and across the buses of the computer for the same amount of data transfer under normal operating conditions.

Level 5

This is the most common type of RAID. By distributing parity across all the member disk drives of an array, RAID level 5 eliminates the write bottleneck inherent in level 4. The only performance bottleneck is the parity calculation process itself. Modern CPUs can calculate parity very fast. However, if you have a large number of disks in a RAID 5 array such that the combined aggregate data transfer speed across all devices is high enough, parity calculation can be a bottleneck.
Level 5 has asymmetrical performance, and reads substantially outperforming writes. The storage capacity of RAID level 5 is calculated the same way as with level 4.

Level 6

This is a common level of RAID when data redundancy and preservation, and not performance, are the paramount concerns, but where the space inefficiency of level 1 is not acceptable. Level 6 uses a complex parity scheme to be able to recover from the loss of any two drives in the array. This complex parity scheme creates a significantly higher CPU burden on software RAID devices and also imposes an increased burden during write transactions. As such, level 6 is considerably more asymmetrical in performance than levels 4 and 5.
The total capacity of a RAID level 6 array is calculated similarly to RAID level 5 and 4, except that you must subtract two devices instead of one from the device count for the extra parity storage space.

Level 10

This RAID level attempts to combine the performance advantages of level 0 with the redundancy of level 1. It also reduces some of the space wasted in level 1 arrays with more than two devices. With level 10, it is possible, for example, to create a 3-drive array configured to store only two copies of each piece of data, which then allows the overall array size to be 1.5 times the size of the smallest devices instead of only equal to the smallest device, similar to a 3-device, level 1 array. This avoids CPU process usage to calculate parity similar to RAID level 6, but it is less space efficient.
The creation of RAID level 10 is not supported during installation. It is possible to create one manually after installation.

Linear RAID

Linear RAID is a grouping of drives to create a larger virtual drive.
In linear RAID, the chunks are allocated sequentially from one member drive, going to the next drive only when the first is completely filled. This grouping provides no performance benefit, as it is unlikely that any I/O operations split between member drives. Linear RAID also offers no redundancy and decreases reliability. If any one member drive fails, the entire array cannot be used and data can be lost. The capacity is the total of all member disks.

18.4. SUPPORTED RAID CONVERSIONS

It is possible to convert from one RAID level to another. For example, you can convert from RAID5 to RAID10, but not from RAID10 to RAID5. The following table describes the supported RAID conversions:

RAID conversion levels	Conversion steps	Notes
RAID level 0 to RAID level 4	**# mdadm --grow /dev/md0 --level=4 -n3 --add /dev/vdd**	You need to add a disk to the MD array because it require at least 3 disks.

RAID conversion levels	Conversion steps	Notes
RAID level 0 to RAID level 5	**# mdadm --grow /dev/md0 --level=5 -n3 --add /dev/vdd**	You need to add a disk to the MD array because it require at least 3 disks.
RAID level 0 to RAID level 10	**# mdadm --grow /dev/md0 --level 10 -n 4 --add /dev/vd[ef]**	You need to add two extra disks to the MD array.
RAID level 1 to RAID level 0	**# mdadm --grow /dev/md0 -l0**	
RAID level 1 to RAID level 5	**# mdadm --grow /dev/md0 --level=5**	
RAID level 4 to RAID level 0	**# mdadm --grow /dev/md0 --level=0**	
RAID level 4 to RAID level 5	**# mdadm --grow /dev/md0 --level=5**	
RAID level 5 to RAID level 0	**# mdadm --grow /dev/md0 --level=0**	
RAID level 5 to RAID level 1	**# mdadm -CR /dev/md0 -l5 -n3 /dev/sd[abc] --assume-clean --size 1G** **# mdadm -D /dev/md0 | grep Level** **# mdadm --grow /dev/md0 --array-size 1048576** **# mdadm --grow -n 2 /dev/md0 --backup=internal** **# mdadm --grow -l1 /dev/md0** **# mdadm -D /dev/md0 | grep Level**	

RAID conversion levels	Conversion steps	Notes
RAID level 5 to RAID level 4	**# mdadm --grow /dev/md0 --level=4**	
RAID level 5 to RAID level 6	**# mdadm --grow /dev/md0 --level=6 --add /dev/vde**	
RAID level 5 to RAID level 10	**# mdadm --grow /dev/md0 --level=0 # mdadm --grow /dev/md0 --level=10 --add /dev/vde /dev/vdf**	Converting RAID level 5 to RAID level 10 is a two step conversion: 1. Convert to RAID level 0 2. Add two additional disks while converting to RAID10.
RAID level 6 to RAID level 5	**# mdadm --grow /dev/md0 --level=5**	
RAID level 10 to RAID level 0	**# mdadm --grow /dev/md0 --level=0**	

NOTE

Converting RAID 5 to RAID0 and RAID4 is only possible with the **ALGORITHM_PARITY_N** layout.

After converting a RAID level, verify the conversion by using either the **mdadm --detail /dev/md0** or **cat /proc/mdstat** command.

Additional resources

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

18.5. RAID SUBSYSTEMS

The following subsystems compose RAID:

Hardware RAID Controller Drivers

Hardware RAID controllers have no specific RAID subsystem. Since they use special RAID chipsets, hardware RAID controllers come with their own drivers. With these drivers, the system detects the RAID sets as regular disks.

mdraid

The **mdraid** subsystem was designed as a software RAID solution. It is also the preferred solution for software RAID in Red Hat Enterprise Linux. This subsystem uses its own metadata format, which is referred to as native MD metadata.
It also supports other metadata formats, known as external metadata. Red Hat Enterprise Linux 9 uses **mdraid** with external metadata to access Intel Rapid Storage (ISW) or Intel Matrix Storage Manager (IMSM) sets and Storage Networking Industry Association (SNIA) Disk Drive Format (DDF). The **mdraid** subsystem sets are configured and controlled through the **mdadm** utility.

18.6. CREATING A SOFTWARE RAID DURING THE INSTALLATION

Redundant Arrays of Independent Disks (RAID) devices are constructed from multiple storage devices that are arranged to provide increased performance and, in some configurations, greater fault tolerance. A RAID device is created in one step and disks are added or removed as necessary. You can configure one RAID partition for each physical disk in your system, so that the number of disks available to the installation program determines the levels of RAID device available. For example, if your system has two disks, you cannot create a **RAID 10** device, as it requires a minimum of three separate disks. To optimize your system's storage performance and reliability, RHEL supports software **RAID 0**, **RAID 1**, **RAID 4**, **RAID 5**, **RAID 6**, and **RAID 10** types with LVM and LVM Thin Provisioning to set up storage on the installed system.

NOTE

On 64-bit IBM Z, the storage subsystem uses RAID transparently. You do not have to configure software RAID manually.

Prerequisites

- You have selected two or more disks for installation before RAID configuration options are visible. Depending on the RAID type you want to create, at least two disks are required.
- You have created a mount point. By configuring a mount point, you can configure the RAID device.
- You have selected the **Custom** radio button on the **Installation Destination** window.

Procedure

1. From the left pane of the **Manual Partitioning** window, select the required partition.
2. Under the **Device(s)** section, click **Modify**. The **Configure Mount Point** dialog box opens.
3. Select the disks that you want to include in the RAID device and click **Select**.
4. Click the **Device Type** drop-down menu and select **RAID**.
5. Click the **File System** drop-down menu and select your preferred file system type.
6. Click the **RAID Level** drop-down menu and select your preferred level of RAID.
7. Click **Update Settings** to save your changes.
8. Click **Done** to apply the settings to return to the **Installation Summary** window.

Additional resources

- Creating a RAID LV with DM integrity
- Managing RAID

18.7. CREATING A SOFTWARE RAID ON AN INSTALLED SYSTEM

You can create a software Redundant Array of Independent Disks (RAID) on an existing system using the **mdadm** utility.

Prerequisites

- The **mdadm** package is installed.
- You have created two or more partitions on your system. For detailed instructions, see Creating a partition with parted.

Procedure

1. Create a RAID of two block devices, for example */dev/sda1* and */dev/sdc1*:

```
# mdadm --create /dev/md0 --level=0 --raid-devices=2 /dev/sda1 /dev/sdc1
mdadm: Defaulting to version 1.2 metadata
mdadm: array /dev/md0 started.
```

   The *level_value* option defines the RAID level.

2. Optional: Check the status of the RAID:

```
# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Oct 13 15:17:39 2022
        Raid Level : raid0
        Array Size : 18649600 (17.79 GiB 19.10 GB)
      Raid Devices : 2
     Total Devices : 2
       Persistence : Superblock is persistent

       Update Time : Thu Oct 13 15:17:39 2022
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0
[...]
```

3. Optional: Observe the detailed information about each device in the RAID:

```
# mdadm --examine /dev/sda1 /dev/sdc1
/dev/sda1:
          Magic : a92b4efc
        Version : 1.2
    Feature Map : 0x1000
```

```
     Array UUID : 77ddfb0a:41529b0e:f2c5cde1:1d72ce2c
           Name : 0
  Creation Time : Thu Oct 13 15:17:39 2022
     Raid Level : raid0
   Raid Devices : 2
[...]
```

4. Create a file system on the RAID drive:

```
# mkfs -t xfs /dev/md0
```

Replace *xfs* with the file system that you chose to format the drive with.

5. Create a mount point for RAID drive and mount it:

```
# mkdir /mnt/raid1
# mount /dev/md0 /mnt/raid1
```

Replace */mnt/raid1* with the mount point.

If you want that RHEL mounts the **md0** RAID device automatically when the system boots, add an entry for your device to the **/etc/fstab file**:

```
/dev/md0   /mnt/raid1 xfs  defaults   0 0
```

18.8. CREATING RAID IN THE WEB CONSOLE

Configure RAID in the RHEL 9 web console.

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 .
- You have installed the **cockpit-storaged** package on your system.
- You have connected physical disks and they are visible by the system.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the panel, click **Storage**.
3. In the **Storage** table, click the menu button and select **Create MDRAID device**.
4. In the **Create RAID Device** field, enter a name for the new RAID.
5. In the **RAID Level** drop-down list, select a level of RAID you want to use.

6. From the **Chunk Size** drop-down list, select the size from the list of available options.
   The **Chunk Size** value specifies how large each block is for data writing. For example, if the chunk size is 512 KiB, the system writes the first 512 KiB to the first disk, the second 512 KiB is written to the second disk, and the third chunk is written to the third disk. If you have three disks in your RAID, the fourth 512 KiB is written to the first disk again.

7. Select the disks you want to use for RAID.

8. Click **Create**.

Verification

- Go to the **Storage** section and check that you can see the new RAID in the **RAID devices** box.

18.9. FORMATTING RAID IN THE WEB CONSOLE

You can format and mount software RAID devices in the RHEL 9 web console.

Formatting can take several minutes depending on the volume size and which formatting options are selected.

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 .
- You have installed the **cockpit-storaged** package.
- You have connected physical disks and they are visible by the system.
- You have created RAID.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. In the panel, click **Storage**.

3. In the **Storage** table, click the menu button ⋮ for the RAID device that you want to format.

4. From the drop-down menu, select **Format**.

5. In the **Format** field, enter a name.

6. In the **Mount Point** field, add the mount path.

7. From the **Type** drop-down list, select the type of file system.

8. Optional: Check the **Overwrite existing data with zeros** option, if the disk includes any sensitive data and you want to overwrite them. Otherwise the RHEL web console rewrites only the disk header.

9. In the **Encryption** drop-down menu, select the type of encryption. If you do not want to encrypt the volume, select **No encryption**.
10. In the **At boot** drop-down menu, select when you want to mount the volume.
11. In the **Mount options** section:
    a. If you want the to mount the volume as a read-only logical volume, select the **Mount read only** checkbox.
    b. If you want to change the default mount option, select the **Custom mount options** checkbox and add the mount options.
12. Format the RAID partition:
    - If you want to format and mount the partition, click the **Format and mount** button.
    - If you want to only format the partition, click the **Format only** button.

Verification

- After the formatting has completed successfully, you can see the details of the formatted logical volume in the **Storage** table on the **Storage** page.

18.10. CREATING A PARTITION TABLE ON RAID BY USING THE WEB CONSOLE

Format RAID with the partition table on the new software RAID device created in the RHEL 9 interface.

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 .
- You have installed the **cockpit-storaged** package.
- You have connected physical disks and they are visible by the system.
- You have created RAID.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the panel, click **Storage**.
3. In the **Storage** table, click the RAID device on which you want to create a partition table.
4. Click the menu button ⋮ in the **MDRAID device** section.
5. From the drop-down menu, select **Create partition table**.

6. In the **Initialize disk** dialog box, select the following:
   a. **Partitioning**:
      - If the partition should be compatible with all systems and devices, select **MBR**.
      - If the partition should be compatible with modern system and hard disks must be greater than 2 TB, select **GPT**.
      - If you do not need partitioning, select **No partitioning**.
   b. **Overwrite**:
      - Check the **Overwrite existing data with zeros** option if the disk includes any sensitive data and you want to overwrite them. Otherwise the RHEL web console rewrites only the disk header.
7. Click **Initialize**.

18.11. CREATING PARTITIONS ON RAID BY USING THE WEB CONSOLE

Create a partition in the existing partition table. You can create more partitions after the partition is created.

Prerequisites

- The RHEL 9 web console is installed and accessible. For details, see Installing the web console.
- The **cockpit-storaged** package is installed on your system.
- A partition table on RAID is created.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the panel, click **Storage**.
3. Click the RAID device on which you want to create a partition.
4. On the RAID device page, scroll to the **GPT partitions** section and click the menu button [⋮].
5. Click **Create partition** and enter a name for the file system in the **Create partition** field. Do not use spaces in the name.
6. In the **Mount Point** field, enter the mount path.
7. In the **Type** drop-down list, select the type of file system.
8. In the **Size** slider, set the size of the partition.
9. Optional: Select **Overwrite existing data with zeros**, if the disk includes any sensitive data and you want to overwrite them. Otherwise the RHEL web console rewrites only the disk header.
10. In the **Encryption** drop-down menu, select the type of encryption. If you do not want to encrypt the volume, select **No encryption**.

11. In the **At boot** drop-down menu, select when you want to mount the volume.
12. In the **Mount options** section:
    a. If you want to mount the volume as a read-only logical volume, select the **Mount read only** checkbox.
    b. If you want to change the default mount option, select the **Custom mount options** checkbox and add the mount options.
13. 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

- You can see the details of the formatted logical volume in the **Storage** table on the main storage page.

18.12. CREATING A VOLUME GROUP ON TOP OF RAID BY USING THE WEB CONSOLE

Build a volume group from software RAID.

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 .
- You have installed the **cockpit-storaged** package.
- You have a RAID device that is not formatted and not mounted.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the panel, click **Storage**.
3. In the **Storage** table, click the menu button [⋮] and select **Create LVM2 volume group**.
4. In the **Create LVM2 volume group** field, enter a name for the new volume group.
5. From the **Disks** list, select a RAID device.
   If you do not see the RAID in the list, unmount the RAID from the system. The RAID device must not be in use by the RHEL 9 system.

6. Click **Create**.

18.13. 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'
```

18.14. EXTENDING RAID

Additional resources

You can extend a RAID using the **--grow** option of the **mdadm** utility.

Prerequisites

- Enough disk space.
- The **parted** package is installed.

Procedure

1. Extend RAID partitions. For more information, see Resizing a partition with parted .
2. Extend RAID to the maximum of the partition capacity:

```
# mdadm --grow --size=max /dev/md0
```

To set a specific size, write the value of the **--size** parameter in kB, for example **--size=*524228***.

3. Increase the size of file system. For example, if the volume uses XFS and is mounted to */mnt/*, enter:

```
# xfs_growfs /mnt/
```

Additional resources

- **mdadm(8)** man page on your system
- Managing file systems

18.15. SHRINKING RAID

You can shrink RAID using the **--grow** option of the **mdadm** utility.

IMPORTANT

The XFS file system does not support shrinking.

Prerequisites

- The **parted** package is installed.

Procedure

1. Shrink the file system. For more information, see Managing file systems.
2. Decrease the RAID to the size, for example to *512 MB*:

```
# mdadm --grow --size=524228 /dev/md0
```

   Write the **--size** parameter in kB.

3. Shrink the partition to the size you need.

Additional resources

- **mdadm(8)** man page on your system
- Resizing a partition with parted

18.16. CONVERTING A ROOT DISK TO RAID1 AFTER INSTALLATION

You can convert a non-RAID root disk to a RAID1 mirror after installing Red Hat Enterprise Linux 9.

Procedure

1. On the x86 architecture complete the steps in the Red Hat Knowledgebase solution How to convert single disk EFI boot to software RAID after installation of Red Hat Enterprise Linux 9.
2. On the PowerPC (PPC) architecture complete the steps in the Red Hat Knowledgebase solution How do I convert my root disk to RAID1 after installation of Red Hat Enterprise Linux 9 .

18.17. CREATING ADVANCED RAID DEVICES

In some cases, you might want to install the operating system on an array that is created before the installation completes. Usually, this means setting up the **/boot** or root file system arrays on a complex RAID device. In such cases, you might need to use array options that are not supported by the Anaconda installer. To work around this, perform the following steps.

NOTE

The limited Rescue Mode of the installer does not include man pages. Both the **mdadm** and **md** man pages contain useful information for creating custom RAID arrays, and might be needed throughout the workaround.

Procedure

1. Insert the install disk.
2. During the initial boot up, select **Rescue Mode** instead of **Install** or **Upgrade**. When the system fully boots into **Rescue mode**, you can see the command line terminal.
3. From this terminal, execute the following commands:
   a. Create RAID partitions on the target hard drives by using the **parted** command.
   b. Manually create raid arrays by using the **mdadm** command from those partitions using any and all settings and options available.
4. Optional: After creating arrays, create file systems on the arrays as well.
5. Reboot the computer and select **Install** or **Upgrade** to install. As the Anaconda installer searches the disks in the system, it finds the pre-existing RAID devices.
6. When asked about how to use the disks in the system, select **Custom Layout** and click **Next**. In the device listing, the pre-existing MD RAID devices are listed.
7. Select a RAID device and click **Edit**.
8. Configure its mount point and optionally the type of file system it should use if you did not create one earlier, and then click **Done**. Anaconda installs to this pre-existing RAID device, preserving the custom options you selected when you created it in Rescue Mode.

18.18. SETTING UP EMAIL NOTIFICATIONS TO MONITOR A RAID

You can set up email alerts to monitor RAID with the **mdadm** tool. Once the **MAILADDR** variable is set to the required email address, the monitoring system sends the alerts to the added email address.

Prerequisites

- The **mdadm** package is installed.
- The mail service is set up.

Procedure

1. Create the **/etc/mdadm.conf** configuration file for monitoring array by scanning the RAID details:

   ```
   # mdadm --detail --scan >> /etc/mdadm.conf
   ```

   Note, that **ARRAY** and **MAILADDR** are mandatory variables.

2. Open the **/etc/mdadm.conf** configuration file with a text editor of your choice and add the **MAILADDR** variable with the mail address for the notification. For example, add new line:

   ```
   MAILADDR example@example.com
   ```

   Here, *example@example.com* is an email address to which you want to receive the alerts from the array monitoring.

3. Save changes in the **/etc/mdadm.conf** file and close it.

Additional resources

- **mdadm.conf(5)** man page on your system

18.19. REPLACING A FAILED DISK IN RAID

You can reconstruct the data from the failed disks using the remaining disks. RAID level and the total number of disks determines the minimum amount of remaining disks needed for a successful data reconstruction.

In this procedure, the */dev/md0* RAID contains four disks. The */dev/sdd* disk has failed and you need to replace it with the */dev/sdf* disk.

Prerequisites

- A spare disk for replacement.
- The **mdadm** package is installed.

Procedure

1. Check the failed disk:
   a. View the kernel logs:

   ```
   # journalctl -k -f
   ```

   b. Search for a message similar to the following:

   ```
   md/raid:md0: Disk failure on sdd, disabling device.

   md/raid:md0: Operation continuing on 3 devices.
   ```

   c. Press **Ctrl**+**C** on your keyboard to exit the **journalctl** program.
2. Mark the failed disk as faulty:

   ```
   # mdadm --manage /dev/md0 --fail /dev/sdd
   ```

3. Optional: Check if the failed disk was marked correctly:

   ```
   # mdadm --detail /dev/md0
   ```

   At the end of the output is a list of disks in the */dev/md0* RAID where the disk */dev/sdd* has the **faulty** status:

   ```
   Number   Major   Minor   RaidDevice State
     0       8       16       0      active sync   /dev/sdb
     1       8       32       1      active sync   /dev/sdc
     -       0       0        2      removed
     3       8       64       3      active sync   /dev/sde

     2       8       48       -      faulty   /dev/sdd
   ```

4. Remove the failed disk from the RAID:

```
# mdadm --manage /dev/md0 --remove /dev/sdd
```

> **WARNING**
>
> If your RAID cannot withstand another disk failure, do not remove any disk until the new disk has the **active sync** status. You can monitor the progress using the **watch cat /proc/mdstat** command.

5. Add the new disk to the RAID:

```
# mdadm --manage /dev/md0 --add /dev/sdf
```

The */dev/md0* RAID now includes the new disk */dev/sdf* and the **mdadm** service will automatically starts copying data to it from other disks.

Verification

- Check the details of the array:

```
# mdadm --detail /dev/md0
```

If this command shows a list of disks in the */dev/md0* RAID where the new disk has **spare rebuilding** status at the end of the output, data is still being copied to it from other disks:

```
Number   Major   Minor   RaidDevice State
   0       8       16       0      active sync   /dev/sdb
   1       8       32       1      active sync   /dev/sdc
   4       8       80       2      spare rebuilding   /dev/sdf
   3       8       64       3      active sync   /dev/sde
```

After data copying is finished, the new disk has an **active sync** status.

Additional resources

- Setting up email notifications to monitor a RAID

18.20. REPAIRING RAID DISKS

You can repair disks in a RAID array by using the **repair** option.

Prerequisites

- The **mdadm** package is installed.

Procedure

1. Check the array for the failed disks behavior:

```
# echo check > /sys/block/md0/md/sync_action
```

   This checks the array and the **/sys/block/md0/md/sync_action** file shows the sync action.

2. Open the **/sys/block/md0/md/sync_action** file with the text editor of your choice and see if there is any message about disk synchronization failures.

3. View the **/sys/block/md0/md/mismatch_cnt** file. If the **mismatch_cnt** parameter is not **0**, it means that the RAID disks need repair.

4. Repair the disks in the array:

```
# echo repair > /sys/block/md0/md/sync_action
```

   This repairs the disks in the array and writes the result into the **/sys/block/md0/md/sync_action** file.

5. View the synchronization progress:

```
# cat /sys/block/md0/md/sync_action
repair

# cat /proc/mdstat
Personalities : [raid0] [raid6] [raid5] [raid4] [raid1]
md0 : active raid1 sdg[1] dm-3[0]
      511040 blocks super 1.2 [2/2] [UU]
unused devices: <none>
```

CHAPTER 19. ENCRYPTING BLOCK DEVICES USING LUKS

By using the disk encryption, you can protect the data on a block device by encrypting it. To access the device's decrypted contents, enter a passphrase or key as authentication. This is important for mobile computers and removable media because it helps to protect the device's contents even if it has been physically removed from the system. The LUKS format is a default implementation of block device encryption in Red Hat Enterprise Linux.

19.1. LUKS DISK ENCRYPTION

Linux Unified Key Setup-on-disk-format (LUKS) provides a set of tools that simplifies managing the encrypted devices. With LUKS, you can encrypt block devices and enable multiple user keys to decrypt a master key. For bulk encryption of the partition, use this master key.

Red Hat Enterprise Linux uses LUKS to perform block device encryption. By default, the option to encrypt the block device is unchecked during the installation. If you select the option to encrypt your disk, the system prompts you for a passphrase every time you boot the computer. This passphrase unlocks the bulk encryption key that decrypts your partition. If you want to modify the default partition table, you can select the partitions that you want to encrypt. This is set in the partition table settings.

Ciphers

The default cipher used for LUKS is **aes-xts-plain64**. The default key size for LUKS is 512 bits. The default key size for LUKS with **Anaconda** XTS mode is 512 bits. The following are the available ciphers:

- Advanced Encryption Standard (AES)
- Twofish
- Serpent

Operations performed by LUKS

- LUKS encrypts entire block devices and is therefore well-suited for protecting contents of mobile devices such as removable storage media or laptop disk drives.
- The underlying contents of the encrypted block device are arbitrary, which makes it useful for encrypting swap devices. This can also be useful with certain databases that use specially formatted block devices for data storage.
- LUKS uses the existing device mapper kernel subsystem.
- LUKS provides passphrase strengthening, which protects against dictionary attacks.
- LUKS devices contain multiple key slots, which means you can add backup keys or passphrases.

IMPORTANT

LUKS is not recommended for the following scenarios:

- Disk-encryption solutions such as LUKS protect the data only when your system is off. After the system is on and LUKS has decrypted the disk, the files on that disk are available to anyone who have access to them.
- Scenarios that require multiple users to have distinct access keys to the same device. The LUKS1 format provides eight key slots and LUKS2 provides up to 32 key slots.
- Applications that require file-level encryption.

Additional resources

- LUKS Project Home Page
- LUKS On-Disk Format Specification
- FIPS 197: Advanced Encryption Standard (AES)

19.2. LUKS VERSIONS IN RHEL

In Red Hat Enterprise Linux, the default format for LUKS encryption is LUKS2. The old LUKS1 format remains fully supported and it is provided as a format compatible with earlier Red Hat Enterprise Linux releases. LUKS2 re-encryption is considered more robust and safe to use as compared to LUKS1 re-encryption.

The LUKS2 format enables future updates of various parts without a need to modify binary structures. Internally it uses JSON text format for metadata, provides redundancy of metadata, detects metadata corruption, and automatically repairs from a metadata copy.

IMPORTANT

Do not use LUKS2 in systems that support only LUKS1.

Since Red Hat Enterprise Linux 9.2, you can use the **cryptsetup reencrypt** command for both the LUKS versions to encrypt the disk.

Online re-encryption

The LUKS2 format supports re-encrypting encrypted devices while the devices are in use. For example, you do not have to unmount the file system on the device to perform the following tasks:

- Changing the volume key
- Changing the encryption algorithm
  When encrypting a non-encrypted device, you must still unmount the file system. You can remount the file system after a short initialization of the encryption.

  The LUKS1 format does not support online re-encryption.

Conversion

In certain situations, you can convert LUKS1 to LUKS2. The conversion is not possible specifically in the following scenarios:

- A LUKS1 device is marked as being used by a Policy-Based Decryption (PBD) Clevis solution. The **cryptsetup** tool does not convert the device when some **luksmeta** metadata are detected.
- A device is active. The device must be in an inactive state before any conversion is possible.

19.3. OPTIONS FOR DATA PROTECTION DURING LUKS2 RE-ENCRYPTION

LUKS2 provides several options that prioritize performance or data protection during the re-encryption process. It provides the following modes for the **resilience** option, and you can select any of these modes by using the **cryptsetup reencrypt --resilience resilience-mode /dev/*<device_ID>*** command, where you can replace ***<device_ID>*** with the ID of your device.

checksum

The default mode. It balances data protection and performance.
This mode stores individual checksums of the sectors in the re-encryption area, which the recovery process can detect for the sectors that were re-encrypted by LUKS2. The mode requires that the block device sector write is atomic.

journal

The safest mode but also the slowest. Since this mode journals the re-encryption area in the binary area, the LUKS2 writes the data twice.

none

The **none** mode prioritizes performance and provides no data protection. It protects the data only against safe process termination, such as the **SIGTERM** signal or the user pressing **Ctrl**+**C** key. Any unexpected system failure or application failure might result in data corruption.

If a LUKS2 re-encryption process terminates unexpectedly by force, LUKS2 can perform the recovery in one of the following ways:

Automatically

By performing any one of the following actions triggers the automatic recovery action during the next LUKS2 device open action:

- Executing the **cryptsetup open** command.
- Attaching the device with the **systemd-cryptsetup** command.

Manually

By using the **cryptsetup repair /dev/*<device_ID>*** command on the LUKS2 device.

Additional resources

- **cryptsetup-reencrypt(8)** and **cryptsetup-repair(8)** man pages on your system

19.4. ENCRYPTING EXISTING DATA ON A BLOCK DEVICE USING LUKS2

You can encrypt the existing data on a not yet encrypted device by using the LUKS2 format. A new LUKS header is stored in the head of the device.

Prerequisites

- The block device has a file system.
- You have backed up your data.

> **WARNING**
>
> You might lose your data during the encryption process due to a hardware, kernel, or human failure. Ensure that you have a reliable backup before you start encrypting the data.

Procedure

1. Unmount all file systems on the device that you plan to encrypt, for example:

```
# umount /dev/mapper/vg00-lv00
```

2. Make free space for storing a LUKS header. Use one of the following options that suits your scenario:
   - In the case of encrypting a logical volume, you can extend the logical volume without resizing the file system. For example:

```
# lvextend -L+32M /dev/mapper/vg00-lv00
```

   - Extend the partition by using partition management tools, such as **parted**.
   - Shrink the file system on the device. You can use the **resize2fs** utility for the ext2, ext3, or ext4 file systems. Note that you cannot shrink the XFS file system.
3. Initialize the encryption:

```
# cryptsetup reencrypt --encrypt --init-only --reduce-device-size 32M /dev/mapper/vg00-lv00
lv00_encrypted

/dev/mapper/lv00_encrypted is now active and ready for online encryption.
```

4. Mount the device:

```
# mount /dev/mapper/lv00_encrypted /mnt/lv00_encrypted
```

5. Add an entry for a persistent mapping to the **/etc/crypttab** file:
   a. Find the **luksUUID**:

```
# cryptsetup luksUUID /dev/mapper/vg00-lv00
```

```
a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325
```

b. Open **/etc/crypttab** in a text editor of your choice and add a device in this file:

```
$ vi /etc/crypttab

lv00_encrypted UUID=a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325 none
```

Replace *a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325* with your device's **luksUUID**.

c. Refresh initramfs with **dracut**:

```
$ dracut -f --regenerate-all
```

6. Add an entry for a persistent mounting to the **/etc/fstab** file:

a. Find the file system's UUID of the active LUKS block device:

```
$ blkid -p /dev/mapper/lv00_encrypted

/dev/mapper/lv00-encrypted: UUID="37bc2492-d8fa-4969-9d9b-bb64d3685aa9"
BLOCK_SIZE="4096" TYPE="xfs" USAGE="filesystem"
```

b. Open **/etc/fstab** in a text editor of your choice and add a device in this file, for example:

```
$ vi /etc/fstab

UUID=37bc2492-d8fa-4969-9d9b-bb64d3685aa9 /home auto rw,user,auto 0
```

Replace *37bc2492-d8fa-4969-9d9b-bb64d3685aa9* with your file system's UUID.

7. Resume the online encryption:

```
# cryptsetup reencrypt --resume-only /dev/mapper/vg00-lv00

Enter passphrase for /dev/mapper/vg00-lv00:
Auto-detected active dm device 'lv00_encrypted' for data device /dev/mapper/vg00-lv00.
Finished, time 00:31.130, 10272 MiB written, speed 330.0 MiB/s
```

Verification

1. Verify if the existing data was encrypted:

```
# cryptsetup luksDump /dev/mapper/vg00-lv00

LUKS header information
Version: 2
Epoch: 4
Metadata area: 16384 [bytes]
Keyslots area: 16744448 [bytes]
UUID: a52e2cc9-a5be-47b8-a95d-6bdf4f2d9325
Label: (no label)
Subsystem: (no subsystem)
```

```
Flags: (no flags)

Data segments:
  0: crypt
 offset: 33554432 [bytes]
 length: (whole device)
 cipher: aes-xts-plain64
[...]
```

2. View the status of the encrypted blank block device:

```
# cryptsetup status lv00_encrypted

/dev/mapper/lv00_encrypted is active and is in use.
  type:    LUKS2
  cipher:  aes-xts-plain64
  keysize: 512 bits
  key location: keyring
  device:  /dev/mapper/vg00-lv00
```

Additional resources

- **cryptsetup(8)**, **cryptsetup-reencrypt(8)**, **lvextend(8)**, **resize2fs(8)**, and **parted(8)** man pages on your system

19.5. ENCRYPTING EXISTING DATA ON A BLOCK DEVICE USING LUKS2 WITH A DETACHED HEADER

You can encrypt existing data on a block device without creating free space for storing a LUKS header. The header is stored in a detached location, which also serves as an additional layer of security. The procedure uses the LUKS2 encryption format.

Prerequisites

- The block device has a file system.
- Your data is backed up.

> **WARNING**
>
> You might lose your data during the encryption process due to a hardware, kernel, or human failure. Ensure that you have a reliable backup before you start encrypting the data.

Procedure

1. Unmount all file systems on the device, for example:

```
# umount /dev/<nvme0n1p1>
```

Replace ***<nvme0n1p1>*** with the device identifier corresponding to the partition you want to unmount.

2. Initialize the encryption:

```
# cryptsetup reencrypt --encrypt --init-only --header </home/header> /dev/<nvme0n1p1>
<nvme_encrypted>

WARNING!
========
Header file does not exist, do you want to create it?

Are you sure? (Type 'yes' in capital letters): YES
Enter passphrase for </home/header>:
Verify passphrase:
/dev/mapper/<nvme_encrypted> is now active and ready for online encryption.
```

Replace:

- ***</home/header>*** with a path to the file with a detached LUKS header. The detached LUKS header has to be accessible to unlock the encrypted device later.
- ***<nvme_encrypted>*** with the name of the device mapper that is created after encryption.

3. Mount the device:

```
# mount /dev/mapper/<nvme_encrypted> /mnt/<nvme_encrypted>
```

4. Add an entry for a persistent mapping to the **/etc/crypttab** file:

```
# <nvme_encrypted> /dev/disk/by-id/<nvme-partition-id> none header=</home/header>
```

Replace ***<nvme-partition-id>*** with the identifier of the NVMe partition.

5. Regenerate initramfs with **dracut**:

```
# dracut -f --regenerate-all -v
```

6. Add an entry for a persistent mounting to the **/etc/fstab** file:

   a. Find the file system's UUID of the active LUKS block device:

   ```
   $ blkid -p /dev/mapper/<nvme_encrypted>

   /dev/mapper/<nvme_encrypted>: UUID="37bc2492-d8fa-4969-9d9b-bb64d3685aa9"
   BLOCK_SIZE="4096" TYPE="xfs" USAGE="filesystem"
   ```

   b. Open **/etc/fstab** in a text editor and add a device in this file, for example:

   ```
   UUID=<file_system_UUID> /home auto rw,user,auto 0
   ```

   Replace ***<file_system_UUID>*** with the file system's UUID found in the previous step.

7. Resume the online encryption:

```
# cryptsetup reencrypt --resume-only --header </home/header> /dev/<nvme0n1p1>

Enter passphrase for /dev/<nvme0n1p1>:
Auto-detected active dm device '<nvme_encrypted>' for data device /dev/<nvme0n1p1>.
Finished, time 00m51s,   10 GiB written, speed 198.2 MiB/s
```

Verification

1. Verify if the existing data on a block device using LUKS2 with a detached header is encrypted:

```
# cryptsetup luksDump </home/header>

LUKS header information
Version:        2
Epoch:          88
Metadata area:  16384 [bytes]
Keyslots area:  16744448 [bytes]
UUID:           c4f5d274-f4c0-41e3-ac36-22a917ab0386
Label:          (no label)
Subsystem:      (no subsystem)
Flags:        (no flags)

Data segments:
  0: crypt
 offset: 0 [bytes]
 length: (whole device)
 cipher: aes-xts-plain64
 sector: 512 [bytes]
[...]
```

2. View the status of the encrypted blank block device:

```
# cryptsetup status <nvme_encrypted>

/dev/mapper/<nvme_encrypted> is active and is in use.
  type:    LUKS2
  cipher:  aes-xts-plain64
  keysize: 512 bits
  key location: keyring
  device:  /dev/<nvme0n1p1>
```

Additional resources

- **cryptsetup(8)** and **cryptsetup-reencrypt(8)** man pages on your system

19.6. ENCRYPTING A BLANK BLOCK DEVICE USING LUKS2

You can encrypt a blank block device, which you can use for an encrypted storage by using the LUKS2 format.

Prerequisites

- A blank block device. You can use commands such as **lsblk** to find if there is no real data on that device, for example, a file system.

Procedure

1. Setup a partition as an encrypted LUKS partition:

```
# cryptsetup luksFormat /dev/nvme0n1p1

WARNING!
========
This will overwrite data on /dev/nvme0n1p1 irrevocably.
Are you sure? (Type 'yes' in capital letters): YES
Enter passphrase for /dev/nvme0n1p1:
Verify passphrase:
```

2. Open an encrypted LUKS partition:

```
# cryptsetup open /dev/nvme0n1p1 nvme0n1p1_encrypted

Enter passphrase for /dev/nvme0n1p1:
```

   This unlocks the partition and maps it to a new device by using the device mapper. To not overwrite the encrypted data, this command alerts the kernel that the device is an encrypted device and addressed through LUKS by using the **/dev/mapper/*device_mapped_name*** path.

3. Create a file system to write encrypted data to the partition, which must be accessed through the device mapped name:

```
# mkfs -t ext4 /dev/mapper/nvme0n1p1_encrypted
```

4. Mount the device:

```
# mount /dev/mapper/nvme0n1p1_encrypted mount-point
```

Verification

1. Verify if the blank block device is encrypted:

```
# cryptsetup luksDump /dev/nvme0n1p1

LUKS header information
Version:        2
Epoch:          3
Metadata area:  16384 [bytes]
Keyslots area:  16744448 [bytes]
UUID:           34ce4870-ffdf-467c-9a9e-345a53ed8a25
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]
[...]
```

2. View the status of the encrypted blank block device:

```
# cryptsetup status nvme0n1p1_encrypted

/dev/mapper/nvme0n1p1_encrypted is active and is in use.
  type:    LUKS2
  cipher:  aes-xts-plain64
  keysize: 512 bits
  key location: keyring
  device:  /dev/nvme0n1p1
  sector size:  512
  offset:  32768 sectors
  size:    20938752 sectors
  mode:    read/write
```

Additional resources

- **cryptsetup(8)**, **cryptsetup-open (8)**, and **cryptsetup-lusFormat(8)** man pages on your system

19.7. CONFIGURING THE LUKS PASSPHRASE IN THE WEB CONSOLE

If you want to add encryption to an existing logical volume on your system, you can only do so through formatting the volume.

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.
- Available existing logical volume without encryption.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the panel, click **Storage**.
3. In the **Storage** table, click the menu button ⋮ for the storage device you want to encrypt and click **Format**.
4. In the **Encryption field**, select the encryption specification, **LUKS1** or **LUKS2**.

5. Set and confirm your new passphrase.
6. Optional: Modify further encryption options.
7. Finalize formatting settings.
8. Click **Format**.

19.8. CHANGING THE LUKS PASSPHRASE IN THE WEB CONSOLE

Change a LUKS passphrase on an encrypted disk or partition in the web console.

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.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the panel, click **Storage**.
3. In the **Storage** table, select the disk with encrypted data.
4. On the disk page, scroll to the **Keys** section and click the edit button.
5. In the **Change passphrase** dialog window:
   a. Enter your current passphrase.
   b. Enter your new passphrase.
   c. Confirm your new passphrase.
6. Click **Save**.

19.9. CHANGING THE LUKS PASSPHRASE BY USING THE COMMAND LINE

Change a LUKS passphrase on an encrypted disk or partition by using the command line. With the **cryptsetup** utility, you can control the encryption process with a variety of configuration options and functions, and integrate it in existing automation workflows.

Prerequisites

- You have **root** privileges or permissions to enter administrative commands with **sudo**.

Procedure

1. Change the existing passphrase on the LUKS encrypted device:

```
# cryptsetup luksChangeKey /dev/<device_ID>
```

Replace ***<device_ID>*** with the device designator, for example, **sda**.

If you have multiple key slots configured, you can specify the slot to work with:

```
# cryptsetup luksChangeKey /dev/<device_ID> --key-slot <slot_number>
```

Replace ***<slot_number>*** with the number of the key slot you want to modify.

2. Insert the current passphrase and the new passphrase:

```
Enter passphrase to be changed:
Enter new passphrase:
Verify passphrase:
```

3. Validate the new passphrase:

```
# cryptsetup --verbose open --test-passphrase /dev/<device_ID>
```

Verification

1. Verify that the new passphrase can unlock the device:

```
Enter passphrase for /dev/<device_ID>:
Key slot <slot_number> unlocked.
Command successful.
```

19.10. 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

CHAPTER 20. USING NVDIMM PERSISTENT MEMORY STORAGE

You can enable and manage various types of storage on Non-Volatile Dual In-line Memory Modules (NVDIMM) devices connected to your system.

For installing Red Hat Enterprise Linux 9 on NVDIMM storage, see Installing to an NVDIMM device instead.

20.1. THE NVDIMM PERSISTENT MEMORY TECHNOLOGY

Non-Volatile Dual In-line Memory Modules (NVDIMM) persistent memory, also called storage class memory or **pmem**, is a combination of memory and storage.

NVDIMM combines the durability of storage with the low access latency and the high bandwidth of dynamic RAM (DRAM). The following are the other advantages of using NVDIMM:

- NVDIMM storage is byte-addressable, which means it can be accessed by using the CPU load and store instructions. In addition to the read() and write() system calls, which are required for accessing traditional block-based storage, NVDIMM also supports direct load and a store programming model.
- The performance characteristics of NVDIMM are similar to DRAM with very low access latency, typically in the tens to hundreds of nanoseconds.
- Data stored on NVDIMM is preserved when the power is off, similar to a persistent memory.
- With the direct access (DAX) technology, applications to memory map storage directly are possible without going through the system page cache. This frees up DRAM for other purposes.

NVDIMM is beneficial in use cases such as:

Databases

The reduced storage access latency on NVDIMM improves database performance.

Rapid restart

Rapid restart is also called the warm cache effect. For example, a file server has none of the file contents in memory after starting. As clients connect and read or write data, that data is cached in the page cache. Eventually, the cache contains mostly hot data. After a reboot, the system must start the process again on traditional storage.
With NVDIMM, it is possible for an application to keep the warm cache across reboots if the application is designed properly. In this example, there would be no page cache involved: the application would cache data directly in the persistent memory.

Fast write-cache

File servers often do not acknowledge a client write request until the data is on durable media. Using NVDIMM as a fast write-cache, enables a file server to acknowledge the write request quickly, and results in low latency.

20.2. NVDIMM INTERLEAVING AND REGIONS

Non-Volatile Dual In-line Memory Modules (NVDIMM) devices support grouping into interleaved regions.

NVDIMM devices can be grouped into interleave sets in the same way as regular dynamic RAM (DRAM). An interleave set is similar to a RAID 0 level (stripe) configuration across multiple DIMMs. An Interleave set is also called a region.

Interleaving has the following advantages:

- NVDIMM devices benefit from increased performance when they are configured into interleave sets.
- Interleaving can combine multiple smaller NVDIMM devices into a larger logical device.

NVDIMM interleave sets are configured in the system BIOS or UEFI firmware. Red Hat Enterprise Linux creates one region device for each interleave set.

20.3. NVDIMM NAMESPACES

Non-Volatile Dual In-line Memory Modules (NVDIMM) regions can be divided into one or more namespaces depending on the size of the label area. Using namespaces, you can access the device using different methods, based on the access modes of the namespace such as **sector**, **fsdax**, **devdax**, and **raw**. For more information, NVDIMM access modes.

Some NVDIMM devices do not support multiple namespaces on a region:

- If your NVDIMM device supports labels, you can subdivide the region into namespaces.
- If your NVDIMM device does not support labels, the region can only contain a single namespace. In that case, Red Hat Enterprise Linux creates a default namespace that covers the entire region.

20.4. NVDIMM ACCESS MODES

You can configure Non-Volatile Dual In-line Memory Modules (NVDIMM) namespaces to use either of the following modes:

sector

Presents the storage as a fast block device. This mode is useful for legacy applications that are not modified to use NVDIMM storage, or for applications that use the full I/O stack, including Device Mapper.
A **sector** device can be used in the same way as any other block device on the system. You can create partitions or file systems on it, configure it as part of a software RAID set, or use it as the cache device for **dm-cache**.

Devices in this mode are available as /**dev**/**pmem*N*s**. After creating the namespace, see the listed **blockdev** value.

devdax, or device direct access (DAX)

With **devdax**, NVDIMM devices support direct access programming as described in the Storage Networking Industry Association (SNIA) Non-Volatile Memory (NVM) Programming Model specification. In this mode, I/O bypasses the storage stack of the kernel. Therefore, no Device Mapper drivers can be used.
Device DAX provides raw access to NVDIMM storage by using a DAX character device node. Data on a **devdax** device can be made durable using CPU cache flushing and fencing instructions. Certain databases and virtual machine hypervisors might benefit from this mode. File systems cannot be created on **devdax** devices.

Devices in this mode are available as /**dev**/**dax*N.M***. After creating the namespace, see the listed **chardev** value.

fsdax, or file system direct access (DAX)

With **fsdax**, NVDIMM devices support direct access programming as described in the Storage Networking Industry Association (SNIA) Non-Volatile Memory (NVM) Programming Model specification. In this mode, I/O bypasses the storage stack of the kernel, and many Device Mapper drivers therefore cannot be used.
You can create file systems on file system DAX devices.

Devices in this mode are available as /**dev**/**pmem*N***. After creating the namespace, see the listed **blockdev** value.

raw

Presents a memory disk that does not support DAX. In this mode, namespaces have several limitations and should not be used.
Devices in this mode are available as /**dev**/**pmem*N***. After creating the namespace, see the listed **blockdev** value.

20.5. INSTALLING NDCTL

You can install the **ndctl** utility to configure and monitor Non-Volatile Dual In-line Memory Modules (NVDIMM) devices.

Procedure

- Install the **ndctl** utility:

```
# dnf install ndctl
```

20.6. CREATING A SECTOR NAMESPACE ON AN NVDIMM TO ACT AS A BLOCK DEVICE

You can configure a Non-Volatile Dual In-line Memory Modules (NVDIMM) device in sector mode, also called legacy mode, to support traditional, block-based storage.

You can either:

- reconfigure an existing namespace to sector mode, or
- create a new sector namespace if there is available space.

Prerequisites

- An NVDIMM device is attached to your system.

20.6.1. Reconfiguring an existing NVDIMM namespace to sector mode

You can reconfigure a Non-Volatile Dual In-line Memory Modules (NVDIMM) namespace to sector mode for using it as a fast block device.

> **WARNING**
>
> Reconfiguring a namespace deletes previously stored data on the namespace.

Prerequisites

- The **ndctl** utility is installed. For more information, see Installing ndctl.

Procedure

1. View the existing namespaces:

```
# ndctl list --namespaces --idle
[
  {
    "dev":"namespace1.0",
    "mode":"raw",
    "size":34359738368,
    "state":"disabled",
    "numa_node":1
  },
  {
    "dev":"namespace0.0",
    "mode":"raw",
    "size":34359738368,
    "state":"disabled",
    "numa_node":0
  }
]
```

2. Reconfigure the selected namespace to the sector mode:

```
# ndctl create-namespace --force --reconfig=namespace-ID --mode=sector
```

Example 20.1. Reconfiguring namespace1.0 in sector mode

```
# ndctl create-namespace --force --reconfig=namespace1.0 --mode=sector
{
  "dev":"namespace1.0",
  "mode":"sector",
  "size":"755.26 GiB (810.95 GB)",
  "uuid":"2509949d-1dc4-4ee0-925a-4542b28aa616",
  "sector_size":4096,
  "blockdev":"pmem1s"
}
```

The reconfigured namespace is now available under the **/dev** directory as the **/dev/pmem1s** file.

Verification

- Verify if the existing namespace on your system is reconfigured:

```
# ndctl list --namespace namespace1.0
[
  {
    "dev":"namespace1.0",
    "mode":"sector",
    "size":810954706944,
    "uuid":"2509949d-1dc4-4ee0-925a-4542b28aa616",
    "sector_size":4096,
    "blockdev":"pmem1s"
  }
]
```

Additional resources

- **ndctl-create-namespace(1)** man page on your system

20.6.2. Creating a new NVDIMM namespace in sector mode

You can create a Non-Volatile Dual In-line Memory Modules (NVDIMM) namespace in sector mode for using it as a fast block device if there is available space in the region.

Prerequisites

- The **ndctl** utility is installed. For more information, see Installing ndctl.
- The NVDIMM device supports labels to create multiple namespaces in a region. You can check this using the following command:

```
# ndctl read-labels nmem0 >/dev/null
  read 1 nmem
```

  This indicates that it read the label of one NVDIMM device. If the value is **0**, it implies that your device does not support labels.

Procedure

1. List the **pmem** regions on your system that have available space. In the following example, space is available in the *region1* and *region0* regions:

```
# ndctl list --regions
[
  {
    "dev":"region1",
    "size":2156073582592,
    "align":16777216,
    "available_size":2117418876928,
    "max_available_extent":2117418876928,
    "type":"pmem",
    "iset_id":-9102197055295954944,
    "badblock_count":1,
```

```
    "persistence_domain":"memory_controller"
  },
  {
    "dev":"region0",
    "size":2156073582592,
    "align":16777216,
    "available_size":2143188680704,
    "max_available_extent":2143188680704,
    "type":"pmem",
    "iset_id":736272362787276936,
    "badblock_count":3,
    "persistence_domain":"memory_controller"
  }
]
```

2. Allocate one or more namespaces on any of the available regions:

```
# ndctl create-namespace --mode=sector --region=regionN --size=namespace-size
```

Example 20.2. Creating a 36-GiB sector namespace on region0

```
# ndctl create-namespace --mode=sector --region=region0 --size=36G
{
  "dev":"namespace0.1",
  "mode":"sector",
  "size":"35.96 GiB (38.62 GB)",
  "uuid":"ff5a0a16-3495-4ce8-b86b-f0e3bd9d1817",
  "sector_size":4096,
  "blockdev":"pmem0.1s"
}
```

The new namespace is now available as **/dev/pmem0.1s**.

Verification

- Verify if the new namespace is created in the sector mode:

```
# ndctl list -RN -n namespace0.1
{
  "regions":[
    {
      "dev":"region0",
      "size":2156073582592,
      "align":16777216,
      "available_size":2104533975040,
      "max_available_extent":2104533975040,
      "type":"pmem",
      "iset_id":736272362787276936,
      "badblock_count":3,
      "persistence_domain":"memory_controller",
      "namespaces":[
        {
          "dev":"namespace0.1",
```

```
            "mode":"sector",
            "size":38615912448,
            "uuid":"ff5a0a16-3495-4ce8-b86b-f0e3bd9d1817",
            "sector_size":4096,
            "blockdev":"pmem0.1s"
          }
        ]
      }
    ]
  }
```

Additional resources

- **ndctl-create-namespace(1)** man page on your system

20.7. CREATING A DEVICE DAX NAMESPACE ON AN NVDIMM

Configure the NVDIMM device that is attached to your system, in device DAX mode to support character storage with direct access capabilities.

Consider the following options:

- Reconfiguring an existing namespace to device DAX mode.
- Creating a new device DAX namespace, if there is space available.

20.7.1. NVDIMM in device direct access mode

Device direct access (device DAX, **devdax**) provides a means for applications to directly access storage, without the involvement of a file system. The benefit of device DAX is that it provides a guaranteed fault granularity, which can be configured using the **--align** option of the **ndctl** utility.

For the Intel 64 and AMD64 architecture, the following fault granularities are supported:

- 4 KiB
- 2 MiB
- 1 GiB

Device DAX nodes support only the following system calls:

- **open()**
- **close()**
- **mmap()**

You can view the supported alignments of your NVDIMM device using the **ndctl list --human --capabilities** command. For example, to view it for the *region0* device, use the **ndctl list --human --capabilities -r region0** command.

NOTE

The **read()** and **write()** system calls are not supported because the device DAX use case is tied to the SNIA Non-Volatile Memory Programming Model.

20.7.2. Reconfiguring an existing NVDIMM namespace to device DAX mode

You can reconfigure an existing Non-Volatile Dual In-line Memory Modules (NVDIMM) namespace to device DAX mode.

WARNING

Reconfiguring a namespace deletes previously stored data on the namespace.

Prerequisites

- The **ndctl** utility is installed. For more information, see Installing ndctl.

Procedure

1. List all namespaces on your system:

```
# ndctl list --namespaces --idle

[
  {
    "dev":"namespace1.0",
    "mode":"raw",
    "size":34359738368,
    "uuid":"ac951312-b312-4e76-9f15-6e00c8f2e6f4"
    "state":"disabled",
    "numa_node":1
  },
  {
    "dev":"namespace0.0",
    "mode":"raw",
    "size":38615912448,
    "uuid":"ff5a0a16-3495-4ce8-b86b-f0e3bd9d1817",
    "state":"disabled",
    "numa_node":0
  }
]
```

2. Reconfigure any namespace:

```
# ndctl create-namespace --force --mode=devdax --reconfig=namespace-ID
```

Example 20.3. Reconfiguring a namespace as device DAX

The following command reconfigures **namespace0.1** for data storage that supports DAX. It is aligned to a 2-MiB fault granularity to ensure that the operating system faults in 2-MiB pages at a time:

```
# ndctl create-namespace --force --mode=devdax --align=2M --reconfig=namespace0.1
{
  "dev":"namespace0.1",
  "mode":"devdax",
  "map":"dev",
  "size":"35.44 GiB (38.05 GB)",
  "uuid":"426d6a52-df92-43d2-8cc7-046241d6d761",
  "daxregion":{
    "id":0,
    "size":"35.44 GiB (38.05 GB)",
    "align":2097152,
    "devices":[
      {
        "chardev":"dax0.1",
        "size":"35.44 GiB (38.05 GB)",
        "target_node":4,
        "mode":"devdax"
      }
    ]
  },
  "align":2097152
}
```

The namespace is now available at the **/dev/dax0.1** path.

Verification

- Verify if the existing namespaces on your system is reconfigured:

```
# ndctl list --namespace namespace0.1
[
  {
    "dev":"namespace0.1",
    "mode":"devdax",
    "map":"dev",
    "size":38048628736,
    "uuid":"426d6a52-df92-43d2-8cc7-046241d6d761",
    "chardev":"dax0.1",
    "align":2097152
  }
]
```

Additional resources

- **ndctl-create-namespace(1)** man page on your system

20.7.3. Creating a new NVDIMM namespace in device DAX mode

You can create a new device DAX namespace on a Non-Volatile Dual In-line Memory Modules (NVDIMM) device if there is available space in the region.

Prerequisites

- The **ndctl** utility is installed. For more information, see Installing ndctl.
- The NVDIMM device supports labels to create multiple namespaces in a region. You can check this using the following command:

```
# ndctl read-labels nmem0 >/dev/null
read 1 nmem
```

  This indicates that it read the label of one NVDIMM device. If the value is **0**, it implies that your device does not support labels.

Procedure

1. List the **pmem** regions on your system that have available space. In the following example, space is available in the *region1* and *region0* regions:

```
# ndctl list --regions
[
  {
    "dev":"region1",
    "size":2156073582592,
    "align":16777216,
    "available_size":2117418876928,
    "max_available_extent":2117418876928,
    "type":"pmem",
    "iset_id":-9102197055295954944,
    "badblock_count":1,
    "persistence_domain":"memory_controller"
  },
  {
    "dev":"region0",
    "size":2156073582592,
    "align":16777216,
    "available_size":2143188680704,
    "max_available_extent":2143188680704,
    "type":"pmem",
    "iset_id":736272362787276936,
    "badblock_count":3,
    "persistence_domain":"memory_controller"
  }
]
```

2. Allocate one or more namespaces on any of the available regions:

```
# ndctl create-namespace --mode=devdax --region=regionN --size=namespace-size
```

Example 20.4. Creating a namespace on a region

The following command creates a 36-GiB device DAX namespace on region0. It is aligned to a 2-MiB fault granularity to ensure that the operating system faults in 2-MiB pages at a time:

```
# ndctl create-namespace --mode=devdax --region=region0 --align=2M --size=36G
{
  "dev":"namespace0.2",
  "mode":"devdax",
  "map":"dev",
  "size":"35.44 GiB (38.05 GB)",
  "uuid":"89d13f41-be6c-425b-9ec7-1e2a239b5303",
  "daxregion":{
    "id":0,
    "size":"35.44 GiB (38.05 GB)",
    "align":2097152,
    "devices":[
      {
        "chardev":"dax0.2",
        "size":"35.44 GiB (38.05 GB)",
        "target_node":4,
        "mode":"devdax"
      }
    ]
  },
  "align":2097152
}
```

The namespace is now available as **/dev/dax0.2**.

Verification

- Verify if the new namespace is created in device DAX mode:

```
# ndctl list -RN -n namespace0.2
{
  "regions":[
    {
      "dev":"region0",
      "size":2156073582592,
      "align":16777216,
      "available_size":2065879269376,
      "max_available_extent":2065879269376,
      "type":"pmem",
      "iset_id":736272362787276936,
      "badblock_count":3,
      "persistence_domain":"memory_controller",
      "namespaces":[
        {
          "dev":"namespace0.2",
          "mode":"devdax",
          "map":"dev",
          "size":38048628736,
          "uuid":"89d13f41-be6c-425b-9ec7-1e2a239b5303",
          "chardev":"dax0.2",
          "align":2097152
```

```
        }
      ]
    }
  ]
}
```

Additional resources

- **ndctl-create-namespace(1)** man page on your system

20.8. CREATING A FILE SYSTEM DAX NAMESPACE ON AN NVDIMM

Configure an NVDIMM device that is attached to your system, in file system DAX mode to support a file system with direct access capabilities.

Consider the following options:

- Reconfiguring an existing namespace to file system DAX mode.
- Creating a new file system DAX namespace if there is available space.

20.8.1. NVDIMM in file system direct access mode

When an NVDIMM device is configured in file system direct access (file system DAX, **fsdax**) mode, you can create a file system on top of it. Any application that performs an **mmap()** operation on a file on this file system gets direct access to its storage. This enables the direct access programming model on NVDIMM.

The following new **-o dax** options are now available, and direct access behavior can be controlled through a file attribute if required:

-o dax=inode

This is the default option when you do not specify any dax option while mounting a file system. Using this option, you can set an attribute flag on files to control if the dax mode can be activated. If required, you can set this flag on individual files.
You can also set this flag on a directory and any files in that directory will be created with the same flag. You can set this attribute flag by using the **xfs_io -c 'chattr +x'** directory-name command.

-o dax=never

With this option, the dax mode will not be enabled even if the dax flag is set to an **inode** mode. This means that the per-inode dax attribute flag is ignored, and files set with this flag will never be direct-access enabled.

-o dax=always

This option is equivalent to the old **-o dax** behavior. With this option, you can activate direct access mode for any file on the file system, regardless of the dax attribute flag.

> **WARNING**
>
> In further releases, **-o dax** might not be supported and if required, you can use **-o dax=always** instead. In this mode, every file might be in the direct-access mode.

Per-page metadata allocation

This mode requires allocating per-page metadata in the system DRAM or on the NVDIMM device itself. The overhead of this data structure is 64 bytes per each 4-KiB page:

- On small devices, the amount of overhead is small enough to fit in DRAM with no problems. For example, a 16-GiB namespace only requires 256 MiB for page structures. Since NVDIMM devices are usually small and expensive, storing the page tracking data structures in DRAM is preferable.
- On NVDIMM devices that are be terabytes in size or larger, the amount of memory required to store the page tracking data structures might exceed the amount of DRAM in the system. One TiB of NVDIMM requires 16 GiB for page structures. As a result, storing the data structures on the NVDIMM itself is preferable in such cases.
  You can configure where per-page metadata are stored using the **--map** option when configuring a namespace:
- To allocate in the system RAM, use **--map=mem**.
- To allocate on the NVDIMM, use **--map=dev**.

20.8.2. Reconfiguring an existing NVDIMM namespace to file system DAX mode

You can reconfigure an existing Non-Volatile Dual In-line Memory Modules (NVDIMM) namespace to file system DAX mode.

> **WARNING**
>
> Reconfiguring a namespace deletes previously stored data on the namespace.

Prerequisites

- The **ndctl** utility is installed. For more information, see Installing ndctl.

Procedure

1. List all namespaces on your system:

```
# ndctl list --namespaces --idle
```

```
[
  {
    "dev":"namespace1.0",
    "mode":"raw",
    "size":34359738368,
    "uuid":"ac951312-b312-4e76-9f15-6e00c8f2e6f4"
    "state":"disabled",
    "numa_node":1
  },
  {
    "dev":"namespace0.0",
    "mode":"raw",
    "size":38615912448,
    "uuid":"ff5a0a16-3495-4ce8-b86b-f0e3bd9d1817",
    "state":"disabled",
    "numa_node":0
  }
]
```

2. Reconfigure any namespace:

```
# ndctl create-namespace --force --mode=fsdax --reconfig=namespace-ID
```

Example 20.5. Reconfiguring a namespace as file system DAX

To use **namespace0.0** for a file system that supports DAX, use the following command:

```
# ndctl create-namespace --force --mode=fsdax --reconfig=namespace0.0
{
  "dev":"namespace0.0",
  "mode":"fsdax",
  "map":"dev",
  "size":"11.81 GiB (12.68 GB)",
  "uuid":"f8153ee3-c52d-4c6e-bc1d-197f5be38483",
  "sector_size":512,
  "align":2097152,
  "blockdev":"pmem0"
}
```

The namespace is now available at the **/dev/pmem0** path.

Verification

- Verify if the existing namespaces on your system is reconfigured:

```
# ndctl list --namespace namespace0.0
[
  {
    "dev":"namespace0.0",
    "mode":"fsdax",
    "map":"dev",
    "size":12681478144,
    "uuid":"f8153ee3-c52d-4c6e-bc1d-197f5be38483",
```

```
    "sector_size":512,
    "align":2097152,
    "blockdev":"pmem0"
  }
]
```

Additional resources

- **ndctl-create-namespace(1)** man page on your system

20.8.3. Creating a new NVDIMM namespace in file system DAX mode

You can create a new file system DAX namespace on a Non-Volatile Dual In-line Memory Modules (NVDIMM) device if there is available space in the region.

Prerequisites

- The **ndctl** utility is installed. For more information, see Installing ndctl.
- The NVDIMM device supports labels to create multiple namespaces in a region. You can check this using the following command:

  ```
  # ndctl read-labels nmem0 >/dev/null
  read 1 nmem
  ```

  This indicates that it read the label of one NVDIMM device. If the value is **0**, it implies that your device does not support labels.

Procedure

1. List the **pmem** regions on your system that have available space. In the following example, space is available in the *region1* and *region0* regions:

   ```
   # ndctl list --regions
   [
     {
       "dev":"region1",
       "size":2156073582592,
       "align":16777216,
       "available_size":2117418876928,
       "max_available_extent":2117418876928,
       "type":"pmem",
       "iset_id":-9102197055295954944,
       "badblock_count":1,
       "persistence_domain":"memory_controller"
     },
     {
       "dev":"region0",
       "size":2156073582592,
       "align":16777216,
       "available_size":2143188680704,
       "max_available_extent":2143188680704,
       "type":"pmem",
       "iset_id":736272362787276936,
   ```

```
    "badblock_count":3,
    "persistence_domain":"memory_controller"
  }
]
```

2. Allocate one or more namespaces on any of the available regions:

```
# ndctl create-namespace --mode=fsdax --region=regionN --size=namespace-size
```

Example 20.6. Creating a namespace on a region

The following command creates a 36-GiB file system DAX namespace on *region0*:

```
# ndctl create-namespace --mode=fsdax --region=region0 --size=36G
{
  "dev":"namespace0.3",
  "mode":"fsdax",
  "map":"dev",
  "size":"35.44 GiB (38.05 GB)",
  "uuid":"99e77865-42eb-4b82-9db6-c6bc9b3959c2",
  "sector_size":512,
  "align":2097152,
  "blockdev":"pmem0.3"
}
```

The namespace is now available as **/dev/pmem0.3**.

Verification

- Verify if the new namespace is created in file system DAX mode:

```
# ndctl list -RN -n namespace0.3
{
  "regions":[
    {
      "dev":"region0",
      "size":2156073582592,
      "align":16777216,
      "available_size":2027224563712,
      "max_available_extent":2027224563712,
      "type":"pmem",
      "iset_id":736272362787276936,
      "badblock_count":3,
      "persistence_domain":"memory_controller",
      "namespaces":[
        {
          "dev":"namespace0.3",
          "mode":"fsdax",
          "map":"dev",
          "size":38048628736,
          "uuid":"99e77865-42eb-4b82-9db6-c6bc9b3959c2",
          "sector_size":512,
          "align":2097152,
```

```
            "blockdev":"pmem0.3"
          }
        ]
      }
    ]
  }
```

Additional resources

- **ndctl-create-namespace(1)** man page on your system

20.8.4. Creating a file system on a file system DAX device

You can create a file system on a file system DAX device and mount the file system. After creating a file system, application can use persistent memory and create files in the *mount-point* directory, open the files, and use the **mmap** operation to map the files for direct access.

Procedure

1. Optional: Create a partition on the file system DAX device. For more information, see Creating a partition with parted.

   NOTE

   When creating partitions on an **fsdax** device, partitions must be aligned on page boundaries. On the Intel 64 and AMD64 architecture, at least 4 KiB alignment is required for the start and end of the partition. 2 MiB is the preferred alignment.

   By default, the **parted** tool aligns partitions on 1 MiB boundaries. For the first partition, specify 2 MiB as the start of the partition. If the size of the partition is a multiple of 2 MiB, all other partitions are also aligned.

2. Create an XFS or ext4 file system on the partition or the NVDIMM device:

   ```
   # mkfs.xfs -d su=2m,sw=1 fsdax-partition-or-device
   ```

   NOTE

   The dax-capable and reflinked files can now co-exist on the file system. However, for an individual file, dax and reflink are mutually exclusive.

   Also, in order to increase the likelihood of large page mappings, set the stripe unit and stripe width.

3. Mount the file system:

   ```
   # mount f_sdax-partition-or-device mount-point_
   ```

   There is no need to mount a file system with the dax option to enable direct access mode. When you do not specify any dax option while mounting, the file system is in the **dax=inode** mode. Set the dax option on the file before direct access mode is activated.

Additional resources

- **mkfs.xfs(8)** man page on your system
- NVDIMM in file system direct access mode

20.9. MONITORING NVDIMM HEALTH USING S.M.A.R.T.

Some Non-Volatile Dual In-line Memory Modules (NVDIMM) devices support Self-Monitoring, Analysis and Reporting Technology (S.M.A.R.T.) interfaces for retrieving health information.

IMPORTANT

Monitor NVDIMM health regularly to prevent data loss. If S.M.A.R.T. reports problems with the health status of an NVDIMM device, replace it as described in Detecting and replacing a broken NVDIMM device.

Prerequisites

- Optional: On some systems, upload the **acpi_ipmi** driver to retrieve health information using the following command:

```
# modprobe acpi_ipmi
```

Procedure

- Access the health information:

```
# ndctl list --dimms --health
[
  {
    "dev":"nmem1",
    "id":"8089-a2-1834-00001f13",
    "handle":17,
    "phys_id":32,
    "security":"disabled",
    "health":{
      "health_state":"ok",
      "temperature_celsius":36.0,
      "controller_temperature_celsius":37.0,
      "spares_percentage":100,
      "alarm_temperature":false,
      "alarm_controller_temperature":false,
      "alarm_spares":false,
      "alarm_enabled_media_temperature":true,
      "temperature_threshold":82.0,
      "alarm_enabled_ctrl_temperature":true,
      "controller_temperature_threshold":98.0,
      "alarm_enabled_spares":true,
      "spares_threshold":50,
      "shutdown_state":"clean",
      "shutdown_count":4
    }
```

```
  },
[...]
]
```

Additional resources

- **ndctl-list(1)** man page on your system

20.10. DETECTING AND REPLACING A BROKEN NVDIMM DEVICE

If you find error messages related to Non-Volatile Dual In-line Memory Modules (NVDIMM) reported in your system log or by S.M.A.R.T., it might mean an NVDIMM device is failing. In that case, it is necessary to:

1. Detect which NVDIMM device is failing
2. Back up data stored on it
3. Physically replace the device

Procedure

1. Detect the broken device:

```
# ndctl list --dimms --regions --health
{
  "dimms":[
    {
      "dev":"nmem1",
      "id":"8089-a2-1834-00001f13",
      "handle":17,
      "phys_id":32,
      "security":"disabled",
      "health":{
        "health_state":"ok",
        "temperature_celsius":35.0,
        [...]
      }
[...]
}
```

2. Find the **phys_id** attribute of the broken NVDIMM:

```
# ndctl list --dimms --human
```

From the previous example, you know that **nmem0** is the broken NVDIMM. Therefore, find the **phys_id** attribute of **nmem0**.

Example 20.7. The phys_id attributes of NVDIMMs

In the following example, the **phys_id** is **0x10**:

```
# ndctl list --dimms --human
```

```
[
  {
    "dev":"nmem1",
    "id":"XXXX-XX-XXXX-XXXXXXXX",
    "handle":"0x120",
    "phys_id":"0x1c"
  },
  {
    "dev":"nmem0",
    "id":"XXXX-XX-XXXX-XXXXXXXX",
    "handle":"0x20",
    "phys_id":"0x10",
    "flag_failed_flush":true,
    "flag_smart_event":true
  }
]
```

3. Find the memory slot of the broken NVDIMM:

```
# dmidecode
```

In the output, find the entry where the **Handle** identifier matches the **phys_id** attribute of the broken NVDIMM. The **Locator** field lists the memory slot used by the broken NVDIMM.

Example 20.8. NVDIMM Memory Slot Listing

In the following example, the **nmem0** device matches the **0x0010** identifier and uses the **DIMM-XXX-YYYY** memory slot:

```
# dmidecode

...
Handle 0x0010, DMI type 17, 40 bytes
Memory Device
        Array Handle: 0x0004
        Error Information Handle: Not Provided
        Total Width: 72 bits
        Data Width: 64 bits
        Size: 125 GB
        Form Factor: DIMM
        Set: 1
        Locator: DIMM-XXX-YYYY
        Bank Locator: Bank0
        Type: Other
        Type Detail: Non-Volatile Registered (Buffered)
...
```

4. Back up all data in the namespaces on the NVDIMM. If you do not back up the data before replacing the NVDIMM, the data will be lost when you remove the NVDIMM from your system.

WARNING

In some cases, such as when the NVDIMM is completely broken, the backup might fail.

To prevent this, regularly monitor your NVDIMM devices using S.M.A.R.T. as described in Monitoring NVDIMM health using S.M.A.R.T. and replace failing NVDIMMs before they break.

5. List the namespaces on the NVDIMM:

```
# ndctl list --namespaces --dimm=DIMM-ID-number
```

Example 20.9. NVDIMM namespaces listing

In the following example, the **nmem0** device contains the **namespace0.0** and **namespace0.2** namespaces, which you need to back up:

```
# ndctl list --namespaces --dimm=0

[
  {
    "dev":"namespace0.2",
    "mode":"sector",
    "size":67042312192,
    "uuid":"XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX",
    "raw_uuid":"XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX",
    "sector_size":4096,
    "blockdev":"pmem0.2s",
    "numa_node":0
  },
  {
    "dev":"namespace0.0",
    "mode":"sector",
    "size":67042312192,
    "uuid":"XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX",
    "raw_uuid":"XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX",
    "sector_size":4096,
    "blockdev":"pmem0s",
    "numa_node":0
  }
]
```

6. Replace the broken NVDIMM physically.

Additional resources

- **ndctl-list(1)** and **dmidecode(8)** man pages on your system

CHAPTER 21. 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.

21.1. 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.

21.2. 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

21.3. 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

21.4. 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'
```

21.5. 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 22. REMOVING STORAGE DEVICES

You can safely remove a storage device from a running system, which helps prevent system memory overload and data loss. Do not remove a storage device on a system where:

- Free memory is less than 5% of the total memory in more than 10 samples per 100.
- Swapping is active (non-zero **si** and **so** columns in the **vmstat** command output).

Prerequisites

- Before you remove a storage device, ensure that you have enough free system memory due to the increased system memory load during an I/O flush. Use the following commands to view the current memory load and free memory of the system:

```
# vmstat 1 100
# free
```

22.1. SAFE REMOVAL OF STORAGE DEVICES

Safely removing a storage device from a running system requires a top-to-bottom approach. Start from the top layer, which typically is an application or a file system, and work towards the bottom layer, which is the physical device.

You can use storage devices in multiple ways, and they can have different virtual configurations on top of physical devices. For example, you can group multiple instances of a device into a multipath device, make it part of a RAID, or you can make it part of an LVM group. Additionally, devices can be accessed via a file system, or they can be accessed directly such as a “raw" device.

While using the top-to-bottom approach, you must ensure that:

- the device that you want to remove is not in use
- all pending I/O to the device is flushed
- the operating system is not referencing the storage device

22.2. REMOVING BLOCK DEVICES AND ASSOCIATED METADATA

To safely remove a block device from a running system, to help prevent system memory overload and data loss you need to first remove metadata from them. Address each layer in the stack, starting with the file system, and proceed to the disk. These actions prevent putting your system into an inconsistent state.

Use specific commands that may vary depending on what type of devices you are removing:

- **lvremove**, **vgremove** and **pvremove** are specific to LVM.
- For software RAID, run **mdadm** to remove the array. For more information, see Managing RAID.
- For block devices encrypted using LUKS, there are specific additional steps. The following procedure will not work for the block devices encrypted using LUKS. For more information, see Encrypting block devices using LUKS.

WARNING

Rescanning the SCSI bus or performing any other action that changes the state of the operating system, without following the procedure documented here can cause delays due to I/O timeouts, devices to be removed unexpectedly, or data loss.

Prerequisites

- You have an existing block device stack containing the file system, the logical volume, and the volume group.
- You ensured that no other applications or services are using the device that you want to remove.
- You backed up the data from the device that you want to remove.
- Optional: If you want to remove a multipath device, and you are unable to access its path devices, disable queueing of the multipath device by running the following command:

  ```
  # multipathd disablequeueing map multipath-device
  ```

  This enables the I/O of the device to fail, allowing the applications that are using the device to shut down.

NOTE

Removing devices with their metadata one layer at a time ensures no stale signatures remain on the disk.

Procedure

1. Unmount the file system:

   ```
   # umount /mnt/mount-point
   ```

2. Remove the file system:

   ```
   # wipefs -a /dev/vg0/myvol
   ```

   If you have added an entry into the **/etc/fstab** file to make a persistent association between the file system and a mount point, edit **/etc/fstab** at this point to remove that entry.

   Continue with the following steps, depending on the type of the device you want to remove:

3. Remove the logical volume (LV) that contained the file system:

   ```
   # lvremove vg0/myvol
   ```

4. If there are no other logical volumes remaining in the volume group (VG), you can safely remove the VG that contained the device:

```
# vgremove vg0
```

5. Remove the physical volume (PV) metadata from the PV device(s):

```
# pvremove /dev/sdc1
```

```
# wipefs -a /dev/sdc1
```

6. Remove the partitions that contained the PVs:

```
# parted /dev/sdc rm 1
```

7. Remove the partition table if you want to fully wipe the device:

```
# wipefs -a /dev/sdc
```

8. Execute the following steps only if you want to physically remove the device:

   - If you are removing a multipath device, execute the following commands:

     a. View all the paths to the device:

     ```
     # multipath -l
     ```

     The output of this command is required in a later step.

     b. Flush the I/O and remove the multipath device:

     ```
     # multipath -f multipath-device
     ```

   - If the device is not configured as a multipath device, or if the device is configured as a multipath device and you have previously passed I/O to the individual paths, flush any outstanding I/O to all device paths that are used:

     ```
     # blockdev --flushbufs device
     ```

     This is important for devices accessed directly where the **umount** or **vgreduce** commands do not flush the I/O.

   - If you are removing a SCSI device, execute the following commands:

     a. Remove any reference to the path-based name of the device, such as ***/dev/sd***, ***/dev/disk/by-path***, or the **major:minor** number, in applications, scripts, or utilities on the system. This ensures that different devices added in the future are not mistaken for the current device.

     b. Remove each path to the device from the SCSI subsystem:

     ```
     # echo 1 > /sys/block/device-name/device/delete
     ```

     Here the ***device-name*** is retrieved from the output of the **multipath -l** command, if the device was previously used as a multipath device.

9. Remove the physical device from a running system. Note that the I/O to other devices does not stop when you remove this device.

Verification

- Verify that the devices you intended to remove are not displaying on the output of **lsblk** command. The following is an example output:

```
# lsblk

NAME   MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
sda      8:0    0    5G  0 disk
sr0     11:0    1 1024M  0 rom
vda    252:0    0   10G  0 disk
|-vda1 252:1    0    1M  0 part
|-vda2 252:2    0  100M  0 part /boot/efi
`-vda3 252:3    0  9.9G  0 part /
```

Additional resources

- **multipath(8)**, **pvremove(8)**, **vgremove(8)**, **lvremove(8)**, **wipefs(8)**, **parted(8)**, **blockdev(8)**, and **umount(8)** man pages on your system

CHAPTER 23. 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

23.1. 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.

23.2. 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

23.3. 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
```

23.4. 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
  ```

23.5. 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.

23.6. 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
```

23.7. 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.

23.8. 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

23.9. 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.

23.10. 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**.

23.11. 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:

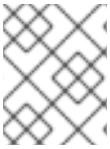
```
# stratis pool overprovision pool-name yes

# 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
```

23.12. 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

23.13. 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.

23.14. 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
```

23.15. 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

23.16. 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
```

23.17. 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 23.1. 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

23.18. 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.

23.19. 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.

23.20. 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.

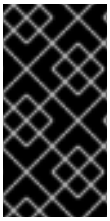
Prerequisites

- 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 24. 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.

24.1. 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

24.2. 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 25. 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.

25.1. 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

25.2. 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 26. 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.

26.1. 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.

26.2. 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

26.3. 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

26.4. 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

26.5. 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 27. 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.

27.1. 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

27.2. 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**.

27.3. 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

27.4. 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**.