Red Hat Enterprise Linux 9

Configuring and managing virtualization

Setting up your host, creating and administering virtual machines, and understanding virtualization features

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Abstract

To use a Red Hat Enterprise Linux (RHEL) system as a virtualization host, follow the instructions in this document. The information provided includes: What the capabilities and use cases of virtualization are How to manage your host and your virtual machines by using command-line utilities, as well as by using the web console What the support limitations of virtualization are on various system architectures, such as Intel 64, AMD64, and IBM Z

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PROVIDING FEEDBACK ON RED HAT DOCUMENTATION

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CHAPTER 1. INTRODUCING VIRTUALIZATION IN RHEL

If you are unfamiliar with the concept of virtualization or its implementation in Linux, the following sections provide a general overview of virtualization in RHEL 9: its basics, advantages, components, and other possible virtualization solutions provided by Red Hat.

1.1. WHAT IS VIRTUALIZATION?

RHEL 9 provides the *virtualization* functionality, which enables a machine running RHEL 9 to *host* multiple virtual machines (VMs), also referred to as *guests*. VMs use the host's physical hardware and computing resources to run a separate, virtualized operating system (*guest OS*) as a user-space process on the host's operating system.

In other words, virtualization makes it possible to have operating systems within operating systems.

VMs enable you to safely test software configurations and features, run legacy software, or optimize the workload efficiency of your hardware. For more information about the benefits, see Advantages of virtualization.

For more information about what virtualization is, see the Virtualization topic page.

Next steps

- To start using virtualization in Red Hat Enterprise Linux 9, see Enabling virtualization in Red Hat Enterprise Linux 9.

- In addition to Red Hat Enterprise Linux 9 virtualization, Red Hat offers a number of specialized virtualization solutions, each with a different user focus and features. For more information, see Red Hat virtualization solutions .

1.2. ADVANTAGES OF VIRTUALIZATION

Using virtual machines (VMs) has the following benefits in comparison to using physical machines:

- **Flexible and fine-grained allocation of resources**
  A VM runs on a host machine, which is usually physical, and physical hardware can also be assigned for the guest OS to use. However, the allocation of physical resources to the VM is done on the software level, and is therefore very flexible. A VM uses a configurable fraction of the host memory, CPUs, or storage space, and that configuration can specify very fine-grained resource requests.

  For example, what the guest OS sees as its disk can be represented as a file on the host file system, and the size of that disk is less constrained than the available sizes for physical disks.

- **Software-controlled configurations**
  The entire configuration of a VM is saved as data on the host, and is under software control. Therefore, a VM can easily be created, removed, cloned, migrated, operated remotely, or connected to remote storage.

- **Separation from the host**
  A guest OS runs on a virtualized kernel, separate from the host OS. This means that any OS can be installed on a VM, and even if the guest OS becomes unstable or is compromised, the host is not affected in any way.

- **Space and cost efficiency**

A single physical machine can host a large number of VMs. Therefore, it avoids the need for multiple physical machines to do the same tasks, and thus lowers the space, power, and maintenance requirements associated with physical hardware.

- **Software compatibility**
  Because a VM can use a different OS than its host, virtualization makes it possible to run applications that were not originally released for your host OS. For example, using a RHEL 7 guest OS, you can run applications released for RHEL 7 on a RHEL 9 host system.

> **NOTE**
>
> Not all operating systems are supported as a guest OS in a RHEL 9 host. For details, see Recommended features in RHEL 9 virtualization .

1.3. VIRTUAL MACHINE COMPONENTS AND THEIR INTERACTION

Virtualization in RHEL 9 consists of the following principal software components:

Hypervisor

The basis of creating virtual machines (VMs) in RHEL 9 is the *hypervisor*, a software layer that controls hardware and enables running multiple operating systems on a host machine.

The hypervisor includes the **Kernel-based Virtual Machine (KVM)**module and virtualization kernel drivers. These components ensure that the Linux kernel on the host machine provides resources for virtualization to user-space software.

At the user-space level, the **QEMU** emulator simulates a complete virtualized hardware platform that the guest operating system can run in, and manages how resources are allocated on the host and presented to the guest.

In addition, the **libvirt** software suite serves as a management and communication layer, making QEMU easier to interact with, enforcing security rules, and providing a number of additional tools for configuring and running VMs.

XML configuration

A host-based XML configuration file (also known as a *domain XML* file) determines all settings and devices in a specific VM. The configuration includes:

- Metadata such as the name of the VM, time zone, and other information about the VM.
- A description of the devices in the VM, including virtual CPUs (vCPUS), storage devices, input/output devices, network interface cards, and other hardware, real and virtual.
- VM settings such as the maximum amount of memory it can use, restart settings, and other settings about the behavior of the VM.

For more information about the contents of an XML configuration, see Sample virtual machine XML configuration.

Component interaction

When a VM is started, the hypervisor uses the XML configuration to create an instance of the VM as a user-space process on the host. The hypervisor also makes the VM process accessible to the host-based interfaces, such as the **virsh**, **virt-install**, and **guestfish** utilities, or the web console GUI.

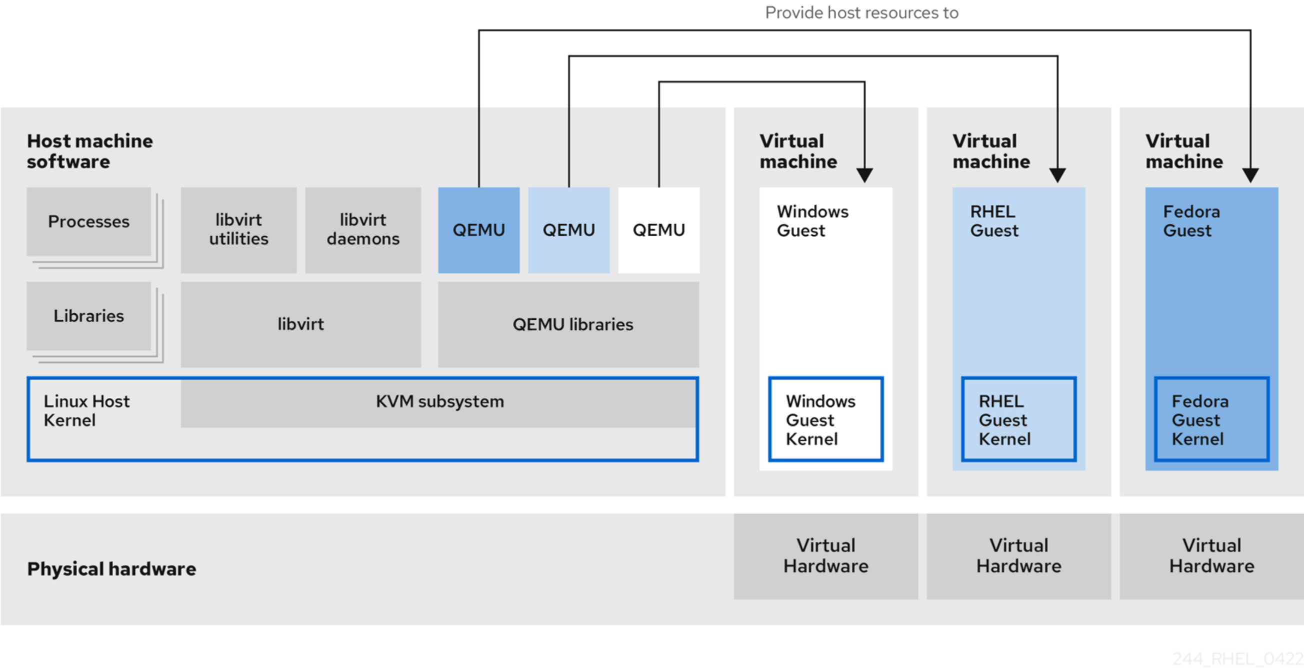
When these virtualization tools are used, libvirt translates their input into instructions for QEMU. QEMU communicates the instructions to KVM, which ensures that the kernel appropriately assigns the resources necessary to carry out the instructions. As a result, QEMU can execute the corresponding user-space changes, such as creating or modifying a VM, or performing an action in the VM's guest operating system.

NOTE

While QEMU is an essential component of the architecture, it is not intended to be used directly on RHEL 9 systems, due to security concerns. Therefore, **qemu-*** commands are not supported by Red Hat, and it is highly recommended to interact with QEMU by using libvirt.

For more information about the host-based interfaces, see Tools and interfaces for virtualization management.

Figure 1.1. RHEL 9 virtualization architecture



1.4. TOOLS AND INTERFACES FOR VIRTUALIZATION MANAGEMENT

You can manage virtualization in RHEL 9 by using the command line (CLI) or several graphical user interfaces (GUIs).

Command-line interface

The CLI is the most powerful method of managing virtualization in RHEL 9. Prominent CLI commands for virtual machine (VM) management include:

- **virsh** - A versatile virtualization command-line utility and shell with a great variety of purposes, depending on the provided arguments. For example:
  - Starting and shutting down a VM - **virsh start** and **virsh shutdown**
  - Listing available VMs - **virsh list**

  - Creating a VM from a configuration file - **virsh create**
  - Entering a virtualization shell - **virsh**

  For more information, see the **virsh(1)** man page on your system.

- **virt-install** - A CLI utility for creating new VMs. For more information, see the **virt-install(1)** man page on your system.
- **virt-xml** - A utility for editing the configuration of a VM.
- **guestfish** - A utility for examining and modifying VM disk images. For more information, see the **guestfish(1)** man page on your system.

Graphical interfaces

You can use the following GUIs to manage virtualization in RHEL 9:

- The **RHEL 9 web console**, also known as *Cockpit*, provides a remotely accessible and easy to use graphical user interface for managing VMs and virtualization hosts.
  For instructions on basic virtualization management with the web console, see Managing virtual machines in the web console.

1.5. RED HAT VIRTUALIZATION SOLUTIONS

The following Red Hat products are built on top of RHEL 9 virtualization features and expand the KVM virtualization capabilities available in RHEL 9. In addition, many limitations of RHEL 9 virtualization do not apply to these products:

OpenShift Virtualization

Based on the KubeVirt technology, OpenShift Virtualization is a part of the Red Hat OpenShift Container Platform, and makes it possible to run virtual machines in containers.
For more information about OpenShift Virtualization see the Red Hat Hybrid Cloud pages.

Red Hat OpenStack Platform (RHOSP)

Red Hat OpenStack Platform offers an integrated foundation to create, deploy, and scale a secure and reliable public or private OpenStack cloud.
For more information about Red Hat OpenStack Platform, see the Red Hat Customer Portal or the Red Hat OpenStack Platform documentation suite .

> **NOTE**
>
> For details on virtualization features not supported in RHEL but supported in other Red Hat virtualization solutions, see: Unsupported features in RHEL 9 virtualization

CHAPTER 2. ENABLING VIRTUALIZATION

To use virtualization in RHEL 9, you must install virtualization packages and ensure your system is configured to host virtual machines (VMs). The specific steps to do this vary based on your CPU architecture.

2.1. ENABLING VIRTUALIZATION ON AMD64 AND INTEL 64

To set up a KVM hypervisor and create virtual machines (VMs) on an AMD64 or Intel 64 system running RHEL 9, follow the instructions below.

Prerequisites

- Red Hat Enterprise Linux 9 is installed and registered on your host machine.
- Your system meets the following hardware requirements to work as a virtualization host:
  - The architecture of your host machine supports KVM virtualization.
  - The following minimum system resources are available:
    - 6 GB free disk space for the host, plus another 6 GB for each intended VM.
    - 2 GB of RAM for the host, plus another 2 GB for each intended VM.
    - 4 CPUs on the host. VMs can generally run with a single assigned vCPU, but Red Hat recommends assigning 2 or more vCPUs per VM to avoid VMs becoming unresponsive during high load.

Procedure

1. Install the virtualization hypervisor packages.

   ```
   # dnf install qemu-kvm libvirt virt-install virt-viewer
   ```

2. Start the virtualization services:

   ```
   # for drv in qemu network nodedev nwfilter secret storage interface; do systemctl start virt${drv}d{,-ro,-admin}.socket; done
   ```

Verification

1. Verify that your system is prepared to be a virtualization host:

   ```
   # virt-host-validate
   [...]
   QEMU: Checking for device assignment IOMMU support         : PASS
   QEMU: Checking if IOMMU is enabled by kernel               : WARN (IOMMU appears to be disabled in kernel. Add intel_iommu=on to kernel cmdline arguments)
   LXC: Checking for Linux >= 2.6.26                          : PASS
   [...]
   LXC: Checking for cgroup 'blkio' controller mount-point    : PASS
   LXC: Checking if device /sys/fs/fuse/connections exists    : FAIL (Load the 'fuse' module to enable /proc/ overrides)
   ```

2. If all **virt-host-validate** checks return a **PASS** value, your system is prepared for creating VMs. If any of the checks return a **FAIL** value, follow the displayed instructions to fix the problem.

   If any of the checks return a **WARN** value, consider following the displayed instructions to improve virtualization capabilities.

Troubleshooting

- If KVM virtualization is not supported by your host CPU, **virt-host-validate** generates the following output:

  ```
  QEMU: Checking for hardware virtualization: FAIL (Only emulated CPUs are available, performance will be significantly limited)
  ```

  However, VMs on such a host system will fail to boot, rather than have performance problems.

  To work around this, you can change the **<domain type>** value in the XML configuration of the VM to **qemu**. Note, however, that Red Hat does not support VMs that use the **qemu** domain type, and setting this is highly discouraged in production environments.

Next steps

- Create a virtual machine on your RHEL 9 host

2.2. ENABLING VIRTUALIZATION ON IBM Z

To set up a KVM hypervisor and create virtual machines (VMs) on an IBM Z system running RHEL 9, follow the instructions below.

Prerequisites

- The following minimum system resources are available:
  - 6 GB free disk space for the host, plus another 6 GB for each intended VM.
  - 2 GB of RAM for the host, plus another 2 GB for each intended VM.
  - 4 CPUs on the host. VMs can generally run with a single assigned vCPU, but Red Hat recommends assigning 2 or more vCPUs per VM to avoid VMs becoming unresponsive during high load.
- Your IBM Z host system is using an IBM z14 CPU or later.
- RHEL 9 is installed on a logical partition (LPAR). In addition, the LPAR supports the *start-interpretive execution* (SIE) virtualization functions.
  To verify this, search for **sie** in your **/proc/cpuinfo** file.

  ```
  # grep sie /proc/cpuinfo
  features        : esan3 zarch stfle msa ldisp eimm dfp edat etf3eh highgprs te sie
  ```

Procedure

1. Install the virtualization packages:

```
# dnf install qemu-kvm libvirt virt-install
```

2. Start the virtualization services:

```
# for drv in qemu network nodedev nwfilter secret storage interface; do systemctl start
virt${drv}d{,-ro,-admin}.socket; done
```

Verification

1. Verify that your system is prepared to be a virtualization host.

```
# virt-host-validate
[...]
QEMU: Checking if device /dev/kvm is accessible             : PASS
QEMU: Checking if device /dev/vhost-net exists              : PASS
QEMU: Checking if device /dev/net/tun exists                : PASS
QEMU: Checking for cgroup 'memory' controller support       : PASS
QEMU: Checking for cgroup 'memory' controller mount-point   : PASS
[...]
```

2. If all **virt-host-validate** checks return a **PASS** value, your system is prepared for creating VMs. If any of the checks return a **FAIL** value, follow the displayed instructions to fix the problem.

   If any of the checks return a **WARN** value, consider following the displayed instructions to improve virtualization capabilities.

Troubleshooting

- If KVM virtualization is not supported by your host CPU, **virt-host-validate** generates the following output:

  ```
  QEMU: Checking for hardware virtualization: FAIL (Only emulated CPUs are available,
  performance will be significantly limited)
  ```

  However, VMs on such a host system will fail to boot, rather than have performance problems.

  To work around this, you can change the **<domain type>** value in the XML configuration of the VM to **qemu**. Note, however, that Red Hat does not support VMs that use the **qemu** domain type, and setting this is highly discouraged in production environments.

Additional resources

- How virtualization on IBM Z differs from AMD64 and Intel 64

2.3. ENABLING VIRTUALIZATION ON ARM 64

To set up a KVM hypervisor for creating virtual machines (VMs) on an ARM 64 system (also known as **AArch64**) that runs RHEL 9, follow the instructions below.

Prerequisites

- The following minimum system resources are available:

  - 6 GB free disk space for the host, plus another 6 GB for each intended guest.
  - 4 GB of RAM for the host, plus another 4 GB for each intended guest.
  - 4 CPUs on the host. VMs can generally run with a single assigned vCPU, but Red Hat recommends assigning 2 or more vCPUs per VM to avoid VMs becoming unresponsive during high load.

Procedure

1. Install the virtualization packages:

   ```
   # dnf install qemu-kvm libvirt virt-install
   ```

2. Start the virtualization services:

   ```
   # for drv in qemu network nodedev nwfilter secret storage interface; do systemctl start
   virt${drv}d{,-ro,-admin}.socket; done
   ```

Verification

1. Verify that your system is prepared to be a virtualization host. Run the following command as root:

   ```
   # virt-host-validate
   [...]
   QEMU: Checking if device /dev/vhost-net exists                : PASS
   QEMU: Checking if device /dev/net/tun exists                  : PASS
   QEMU: Checking for cgroup 'memory' controller support         : PASS
   QEMU: Checking for cgroup 'memory' controller mount-point     : PASS
   [...]
   QEMU: Checking for cgroup 'blkio' controller support          : PASS
   QEMU: Checking for cgroup 'blkio' controller mount-point      : PASS
   QEMU: Checking if IOMMU is enabled by kernel                  : PASS
   ```

2. If all **virt-host-validate** checks return a **PASS** value, your system is prepared for creating virtual machines.
   If any of the checks return a **FAIL** value, follow the displayed instructions to fix the problem.

   If any of the checks return a **WARN** value, consider following the displayed instructions to improve virtualization capabilities.

Next steps

- Creating virtual machines

Additional resources

- How virtualization on ARM 64 differs from AMD64 and Intel 64

2.4. ENABLING QEMU GUEST AGENT FEATURES ON YOUR VIRTUAL MACHINES

To use certain features on a virtual machine (VM) hosted on your RHEL 9 system, you must first configure the VM to use the QEMU Guest Agent (GA).

For a complete list of these features, see Virtualization features that require QEMU Guest Agent .

The specific steps required to configure QEMU GA on a VM differ based on the guest operating system used by the VM:

- For Linux VMs, see Enabling QEMU Guest Agent on Linux guests .
- For Windows VMs, see Enabling QEMU Guest Agent on Windows guests .

2.4.1. Enabling QEMU Guest Agent on Linux guests

To allow a RHEL host to perform a certain subset of operations on a Linux virtual machine (VM), you must enable the QEMU Guest Agent (GA).

You can enable QEMU GA both on running and shut-down VMs.

Procedure

1. Create an XML configuration file for the QEMU GA, for example named **qemuga.xml**:

   ```
   # touch qemuga.xml
   ```

2. Add the following lines to the file:

   ```
   <channel type='unix'>
     <source mode='bind' path='/var/lib/libvirt/qemu/f16x86_64.agent'/>
     <target type='virtio' name='org.qemu.guest_agent.0'/>
   </channel>
   ```

3. Use the XML file to add QEMU GA to the configuration of the VM.
   - If the VM is running, use the following command:

     ```
     # virsh attach-device <vm-name> qemuga.xml --live --config
     ```

   - If the VM is shut-down, use the following command:

     ```
     # virsh attach-device <vm-name> qemuga.xml --config
     ```

4. In the Linux guest operating system, install the QEMU GA:

   ```
   # dnf install qemu-guest-agent
   ```

5. Start the QEMU GA service on the guest:

   ```
   # systemctl start qemu-guest-agent
   ```

Verification

To ensure that QEMU GA is enabled and running on the Linux VM, do any of the following:

- In the guest operating system, use the **systemctl status qemu-guest-agent | grep Loaded** command. If the output includes **enabled**, QEMU GA is active on the VM.
- Use the **virsh domfsinfo *<vm-name>*** command on the host. If it displays any output, QEMU GA is active on the specified VM.

Additional resources

- Virtualization features that require QEMU Guest Agent

2.4.2. Enabling QEMU Guest Agent on Windows guests

To allow a RHEL host to perform a certain subset of operations on a Windows virtual machine (VM), you must enable the QEMU Guest Agent (GA). To do so, add a storage device that contains the QEMU Guest Agent installer to an existing VM or when creating a new VM, and install the drivers on the Windows guest operating system.

To install the Guest Agent (GA) by using the graphical interface, see the procedure below. To install the GA on the command line, use the Microsoft Windows Installer (MSI) .

Prerequisites

- An installation medium with the Guest Agent is attached to the VM. For instructions on preparing the medium, see Preparing virtio driver installation media on a host machine .

Procedure

1. In the Windows guest operating system, open the **File Explorer** application.
2. Click **This PC**.
3. In the **Devices and drives** pane, open the **virtio-win** medium.
4. Open the **guest-agent** folder.
5. Based on the operating system installed on the VM, run one of the following installers:
   - If using a 32-bit operating system, run the **qemu-ga-i386.msi** installer.
   - If using a 64-bit operating system, run the **qemu-ga-x86_64.msi** installer.
6. Optional: If you want to use the para-virtualized serial driver (**virtio-serial**) as the communication interface between the host and the Windows guest, verify that the **virtio-serial** driver is installed on the Windows guest. For more information about installing **virtio** drivers, see: Installing virtio drivers on a Windows guest .

Verification

1. On your Windows VM, navigate to the **Services** window.
   Computer Management > Services
2. Ensure that the status of the **QEMU Guest Agent** service is **Running**.

Additional resources

- Virtualization features that require QEMU Guest Agent

2.4.3. Virtualization features that require QEMU Guest Agent

If you enable QEMU Guest Agent (GA) on a virtual machine (VM), you can use the following commands on your host to manage the VM:

virsh shutdown --mode=agent

This shutdown method is more reliable than **virsh shutdown --mode=acpi**, because **virsh shutdown** used with QEMU GA is guaranteed to shut down a cooperative guest in a clean state.

virsh domfsfreeze and **virsh domfsthaw**

Freezes the guest file system in isolation.

virsh domfstrim

Instructs the guest to trim its file system, which helps to reduce the data that needs to be transferred during migrations.

IMPORTANT

If you want to use this command to manage a Linux VM, you must also set the following SELinux boolean in the guest operating system:

```
# setsebool virt_qemu_ga_read_nonsecurity_files on
```

virsh domtime

Queries or sets the guest's clock.

virsh setvcpus --guest

Instructs the guest to take CPUs offline, which is useful when CPUs cannot be hot-unplugged.

virsh domifaddr --source agent

Queries the guest operating system's IP address by using QEMU GA. For example, this is useful when the guest interface is directly attached to a host interface.

virsh domfsinfo

Shows a list of mounted file systems in the running guest.

virsh set-user-password

Sets the password for a given user account in the guest.

virsh set-user-sshkeys

Edits the authorized SSH keys file for a given user in the guest.

IMPORTANT

If you want to use this command to manage a Linux VM, you must also set the following SELinux boolean in the guest operating system:

```
# setsebool virt_qemu_ga_manage_ssh on
```

Additional resources

- Enabling QEMU Guest Agent on Linux guests
- Enabling QEMU Guest Agent on Windows guests

CHAPTER 3. CREATING VIRTUAL MACHINES

To create a virtual machine (VM) in RHEL 9, use the command line or the RHEL 9 web console.

3.1. CREATING VIRTUAL MACHINES BY USING THE COMMAND LINE

To create a virtual machine (VM) on your RHEL 9 by using the command line, use the **virt-install** utility.

Prerequisites

- Virtualization is enabled on your host system.
- You have a sufficient amount of system resources to allocate to your VMs, such as disk space, RAM, or CPUs. The recommended values might vary significantly depending on the intended tasks and workload of the VMs.
- An operating system (OS) installation source is available locally or on a network. This can be one of the following:
  - An ISO image of an installation medium
  - A disk image of an existing VM installation

  > **WARNING**
  >
  > Installing from a host CD-ROM or DVD-ROM device is not possible in RHEL 9. If you select a CD-ROM or DVD-ROM as the installation source when using any VM installation method available in RHEL 9, the installation will fail. For more information, see the Red Hat Knowledgebase solution RHEL 7 or higher can't install guest OS from CD/DVD-ROM.

  Also note that Red Hat provides support only for a limited set of guest operating systems .
- Optional: A Kickstart file can be provided for faster and easier configuration of the installation.

Procedure

To create a VM and start its OS installation, use the **virt-install** command, along with the following mandatory arguments:

- **--name**: the name of the new machine
- **--memory**: the amount of allocated memory
- **--vcpus**: the number of allocated virtual CPUs
- **--disk**: the type and size of the allocated storage
- **--cdrom** or **--location**: the type and location of the OS installation source

- **--osinfo**: the OS type and version that you intend to install

> **NOTE**
>
> To list all available values for the **--osinfo** argument, run the **virt-install --osinfo list** command.
>
> For more details, install the **libosinfo-bin** package and run the **osinfo-query os** command.

Based on the chosen installation method, the necessary options and values can vary. See the commands below for examples:

- The following command creates a VM named **demo-guest1** that installs the Windows 10 OS from an ISO image locally stored in the **/home/username/Downloads/Win10install.iso** file. This VM is also allocated with 2048 MiB of RAM and 2 vCPUs, and an 80 GiB qcow2 virtual disk is automatically configured for the VM.

```
# virt-install \
    --name demo-guest1 --memory 2048 \
    --vcpus 2 --disk size=80 --osinfo win10 \
    --cdrom /home/username/Downloads/Win10install.iso
```

- The following command creates a VM named **demo-guest2** that uses the **/home/username/Downloads/rhel9.iso** image to run a RHEL 9 OS from a live CD. No disk space is assigned to this VM, so changes made during the session will not be preserved. In addition, the VM is allocated with 4096 MiB of RAM and 4 vCPUs.

```
# virt-install \
    --name demo-guest2 --memory 4096 --vcpus 4 \
    --disk none --livecd --osinfo rhel9.0 \
    --cdrom /home/username/Downloads/rhel9.iso
```

- The following command creates a RHEL 9 VM named **demo-guest3** that connects to an existing disk image, **/home/username/backup/disk.qcow2**. This is similar to physically moving a hard drive between machines, so the OS and data available to demo-guest3 are determined by how the image was handled previously. In addition, this VM is allocated with 2048 MiB of RAM and 2 vCPUs.

```
# virt-install \
    --name demo-guest3 --memory 2048 --vcpus 2 \
    --os-info rhel9.0 --import \
    --disk /home/username/backup/disk.qcow2
```

- The following command creates a VM named **demo-guest4** that installs from the **http://example.com/OS-install** URL. For the installation to start successfully, the URL must contain a working OS installation tree. In addition, the OS is automatically configured by using the **/home/username/ks.cfg** kickstart file. This VM is also allocated with 2048 MiB of RAM, 2 vCPUs, and a 160 GiB qcow2 virtual disk.

```
# virt-install \
    --name demo-guest4 --memory 2048 --vcpus 2 --disk size=160 \
    --osinfo rhel9.0 --location http://example.com/OS-install \
    --initrd-inject /home/username/ks.cfg --extra-args="inst.ks=file:/ks.cfg console=tty0
console=ttyS0,115200n8"
```

In addition, if you want to host demo-guest4 on an RHEL 9 on an ARM 64 host, include the following lines to ensure that the kickstart file installs the **kernel-64k** package:

```
%packages
-kernel
kernel-64k
%end
```

- The following command creates a VM named **demo-guest5** that installs from a **RHEL9.iso** image file in text-only mode, without graphics. It connects the guest console to the serial console. The VM has 16384 MiB of memory, 16 vCPUs, and 280 GiB disk. This kind of installation is useful when connecting to a host over a slow network link.

```
# virt-install \
    --name demo-guest5 --memory 16384 --vcpus 16 --disk size=280 \
    --osinfo rhel9.0 --location RHEL9.iso \
    --graphics none --extra-args='console=ttyS0'
```

- The following command creates a VM named **demo-guest6**, which has the same configuration as demo-guest5, but resides on the 192.0.2.1 remote host.

```
# virt-install \
    --connect qemu+ssh://root@192.0.2.1/system --name demo-guest6 --memory 16384 \
    --vcpus 16 --disk size=280 --osinfo rhel9.0 --location RHEL9.iso \
    --graphics none --extra-args='console=ttyS0'
```

- The following command creates a VM named **demo-guest-7**, which has the same configuration as demo-guest5, but for its storage, it uses an IBM Z DASD mediated device **mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8**, and assigns it device number **1111**.

```
# virt-install \
    --name demo-guest7 --memory 16384 --vcpus 16 --disk size=280 \
    --osinfo rhel9.0 --location RHEL9.iso --graphics none \
    --disk none --hostdev
mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8,address.type=ccw,address.cssid
=0xfe,address.ssid=0x0,address.devno=0x1111,boot-order=1 \
    --extra-args 'rd.dasd=0.0.1111'
```

Note that the name of the mediated device available for installation can be retrieved by using the **virsh nodedev-list --cap mdev** command.

- The following command creates a VM named **demo-guest-8**, which has the same configuration as demo-guest5, but provides the host device **pci_0003_00_00_0** for networking and configures graphics for a graphical installation.

```
# virt-install \
    --name demo-guest8 --memory 16384 --vcpus 16 --disk size=280 \
    --os-variant rhel9.0 --location RHEL9.iso --graphics vnc,listen=0.0.0.0,5901 \
    --input keyboard,bus=virtio --input mouse,bus=virtio \
    --hostdev pci_0003_00_00_0 --network none'
```

Note that the name of the host device available for installation can be retrieved by using the **virsh nodedev-list --cap pci** command. To use the installation GUI, you can connect any VNC viewer to the host's IP at VNC port 5901 when the installation starts. However, you might have to open this port in the firewall first, for example:

```
# firewall-cmd --add-port 5901/tcp
```

Verification

- If the VM is created successfully, a virt-viewer window opens with a graphical console of the VM and starts the guest OS installation.

Troubleshooting

- If **virt-install** fails with a **cannot find default network** error:
  - Ensure that the **libvirt-daemon-config-network** package is installed:

    ```
    # {PackageManagerCommand} info libvirt-daemon-config-network
    Installed Packages
    Name         : libvirt-daemon-config-network
    [...]
    ```

  - Verify that the **libvirt** default network is active and configured to start automatically:

    ```
    # virsh net-list --all
     Name      State    Autostart   Persistent
    --------------------------------------------
     default   active   yes         yes
    ```

  - If it is not, activate the default network and set it to auto-start:

    ```
    # virsh net-autostart default
    Network default marked as autostarted

    # virsh net-start default
    Network default started
    ```

    - If activating the default network fails with the following error, the **libvirt-daemon-config-network** package has not been installed correctly.

      ```
      error: failed to get network 'default'
      error: Network not found: no network with matching name 'default'
      ```

      To fix this, re-install **libvirt-daemon-config-network**:

      ```
      # {PackageManagerCommand} reinstall libvirt-daemon-config-network
      ```

    - If activating the default network fails with an error similar to the following, a conflict has occurred between the default network's subnet and an existing interface on the host.

      ```
      error: Failed to start network default
      error: internal error: Network is already in use by interface ens2
      ```

- To fix this, use the **virsh net-edit default** command and change the **192.0.2.*** values in the configuration to a subnet not already in use on the host.

Additional resources

- **virt-install (1)** man page on your system
- Creating virtual machines and installing guest operating systems by using the web console
- Cloning virtual machines

3.2. CREATING VIRTUAL MACHINES AND INSTALLING GUEST OPERATING SYSTEMS BY USING THE WEB CONSOLE

To manage virtual machines (VMs) in a GUI on a RHEL 9 host, use the web console. The following sections provide information about how to use the RHEL 9 web console to create VMs and install guest operating systems on them.

3.2.1. Creating virtual machines by using the web console

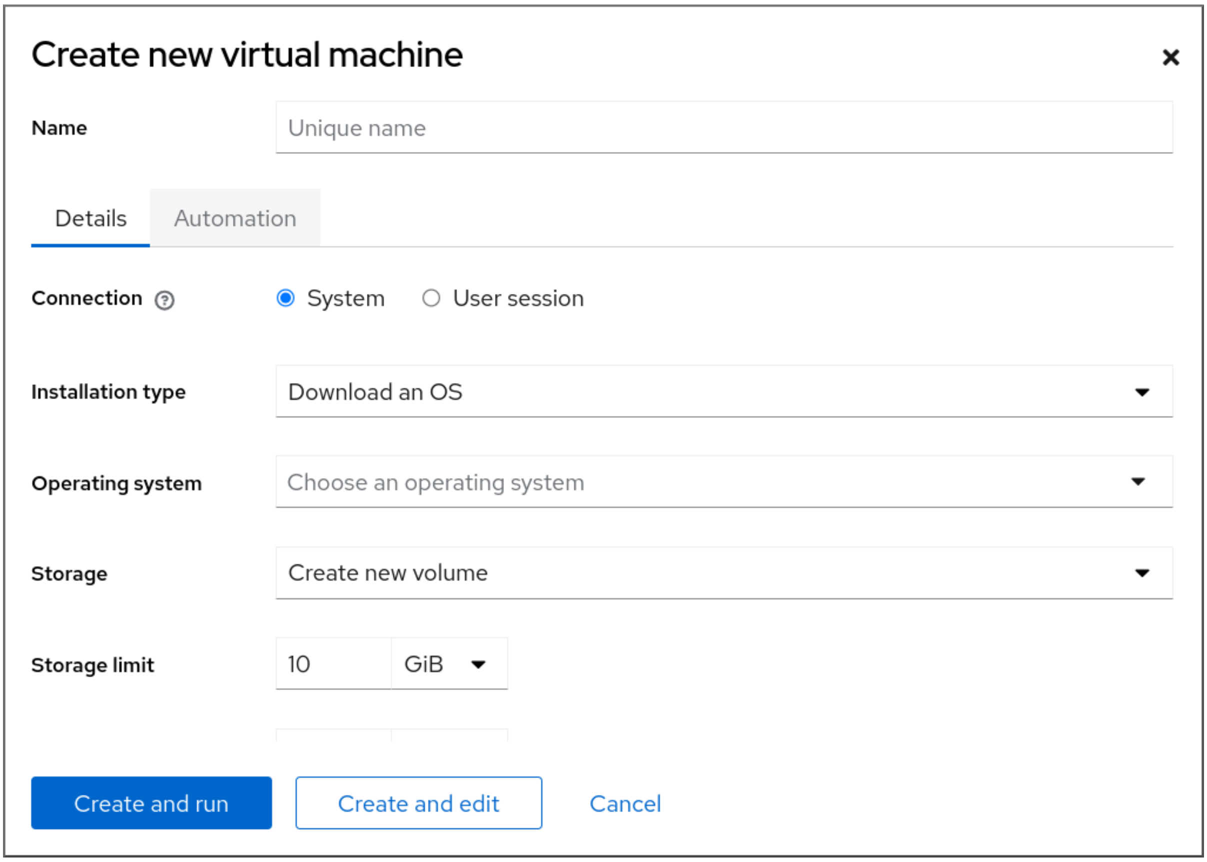
To create a virtual machine (VM) on a host machine to which your RHEL 9 web console is connected, use the instructions below.

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 .
- Virtualization is enabled on your host system .
- The web console VM plug-in is installed on your host system .
- You have a sufficient amount of system resources to allocate to your VMs, such as disk space, RAM, or CPUs. The recommended values might vary significantly depending on the intended tasks and workload of the VMs.

Procedure

1. In the **Virtual Machines** interface of the web console, click **Create VM**.
   The **Create new virtual machine** dialog appears.



Create new virtual machine

Name: Unique name

Connection: ● System ○ User session

Installation type: Download an OS

Operating system: Choose an operating system

Storage: Create new volume

Storage limit: 10 GiB

2. Enter the basic configuration of the VM you want to create.
   - **Name** - The name of the VM.
   - **Connection** - The level of privileges granted to the session. For more details, expand the associated dialog box in the web console.
   - **Installation type** - The installation can use a local installation medium, a URL, a PXE network boot, a cloud base image, or download an operating system from a limited set of operating systems.
   - **Operating system** - The guest operating system running on the VM. Note that Red Hat provides support only for a limited set of guest operating systems .

     NOTE

     To download and install Red Hat Enterprise Linux directly from web console, you must add an offline token in the **Offline token** field.

   - **Storage** - The type of storage.
   - **Storage Limit** - The amount of storage space.
   - **Memory** - The amount of memory.
3. Create the VM:
   - If you want the VM to automatically install the operating system, click **Create and run**.
   - If you want to edit the VM before the operating system is installed, click **Create and edit**.

Next steps

- Installing guest operating systems by using the web console

Additional resources

- Creating virtual machines by using the command line

3.2.2. Creating virtual machines by importing disk images by using the web console

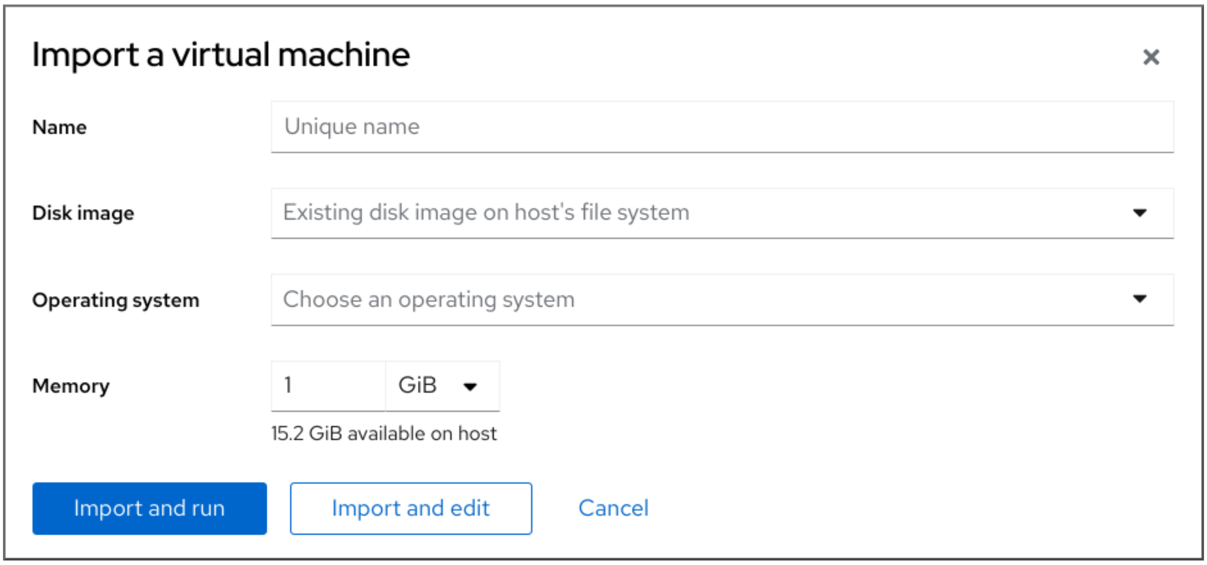
You can create a virtual machine (VM) by importing a disk image of an existing VM installation in the RHEL 9 web console.

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 .
- The web console VM plug-in is installed on your system .
- You have a sufficient amount of system resources to allocate to your VMs, such as disk space, RAM, or CPUs. The recommended values can vary significantly depending on the intended tasks and workload of the VMs.
- You have downloaded a disk image of an existing VM installation.

Procedure

1. In the **Virtual Machines** interface of the web console, click **Import VM**.
   The **Import a virtual machine dialog** appears.



Import a virtual machine

Name: Unique name

Disk image: Existing disk image on host's file system

Operating system: Choose an operating system

Memory: 1 GiB

15.2 GiB available on host

2. Enter the basic configuration of the VM you want to create:

   - **Name** - The name of the VM.

- **Disk image** - The path to the existing disk image of a VM on the host system.
- **Operating system** - The operating system running on a VM disk. Note that Red Hat provides support only for a limited set of guest operating systems .
- **Memory** - The amount of memory to allocate for use by the VM.

3. Import the VM:
    - To install the operating system on the VM without additional edits to the VM settings, click **Import and run**.
    - To edit the VM settings before the installation of the operating system, click **Import and edit**.

3.2.3. Installing guest operating systems by using the web console

When a virtual machine (VM) boots for the first time, you must install an operating system on the VM.

NOTE

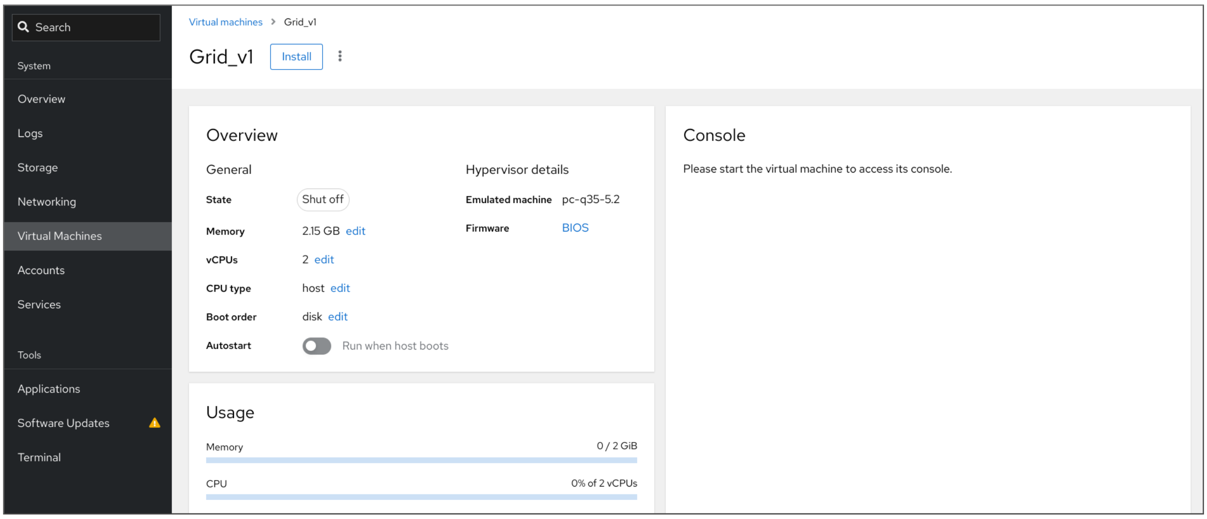
If you click **Create and run** or **Import and run** while creating a new VM, the installation routine for the operating system starts automatically when the VM is created.

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 web console VM plug-in is installed on your host system .

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the VM on which you want to install a guest OS.
   A new page opens with basic information about the selected VM and controls for managing various aspects of the VM.



Grid_v1

Overview

General

State	Shut off
Memory	2.15 GB edit
vCPUs	2 edit
CPU type	host edit
Boot order	disk edit
Autostart	Run when host boots

Hypervisor details

Emulated machine	pc-q35-5.2
Firmware	BIOS

Console

Please start the virtual machine to access its console.

Usage

Memory 0 / 2 GiB

CPU 0% of 2 vCPUs

3. Optional: Change the firmware.

NOTE

You can change the firmware only if you selected **Create and edit** or **Import and edit** while creating a new VM and if the OS is not already installed on the VM.

+ .. Click the firmware.

a. In the **Change Firmware** window, select the required firmware.

b. Click **Save**.

4. Click **Install**.
   The installation routine of the operating system runs in the VM console.

Troubleshooting

- If the installation routine fails, delete and recreate the VM before starting the installation again.

3.2.4. Creating virtual machines with cloud image authentication by using the web console

By default, distro cloud images have no login accounts. However, by using the RHEL web console, you can now create a virtual machine (VM) and specify the root and user account login credentials, which are then passed to cloud-init.

Prerequisites

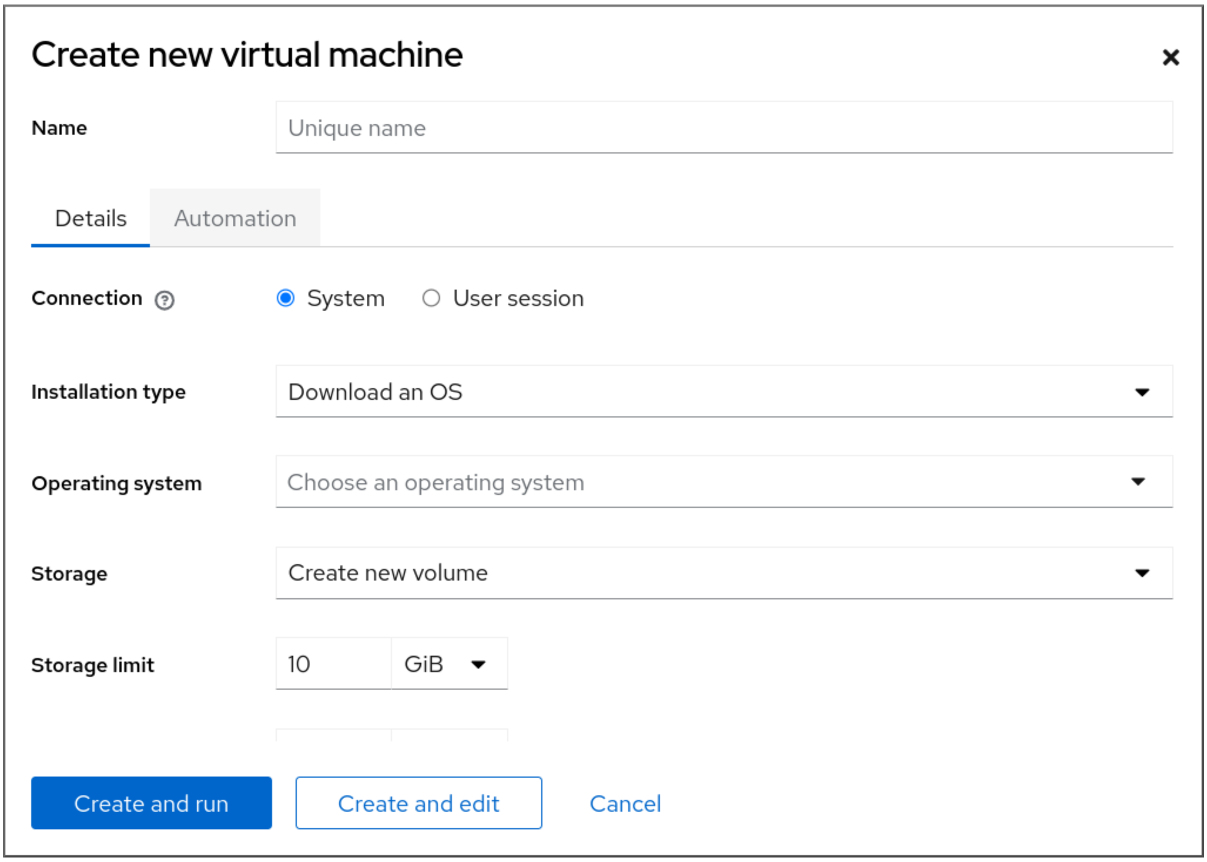
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The web console VM plug-in is installed on your system .
- Virtualization is enabled on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

- You have a sufficient amount of system resources to allocate to your VMs, such as disk space, RAM, or CPUs. The recommended values may vary significantly depending on the intended tasks and workload of the VMs.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. In the **Virtual Machines** interface of the web console, click **Create VM**.
   The Create new virtual machine dialog appears.



Create new virtual machine

Name: Unique name

Connection: ● System ○ User session

Installation type: Download an OS

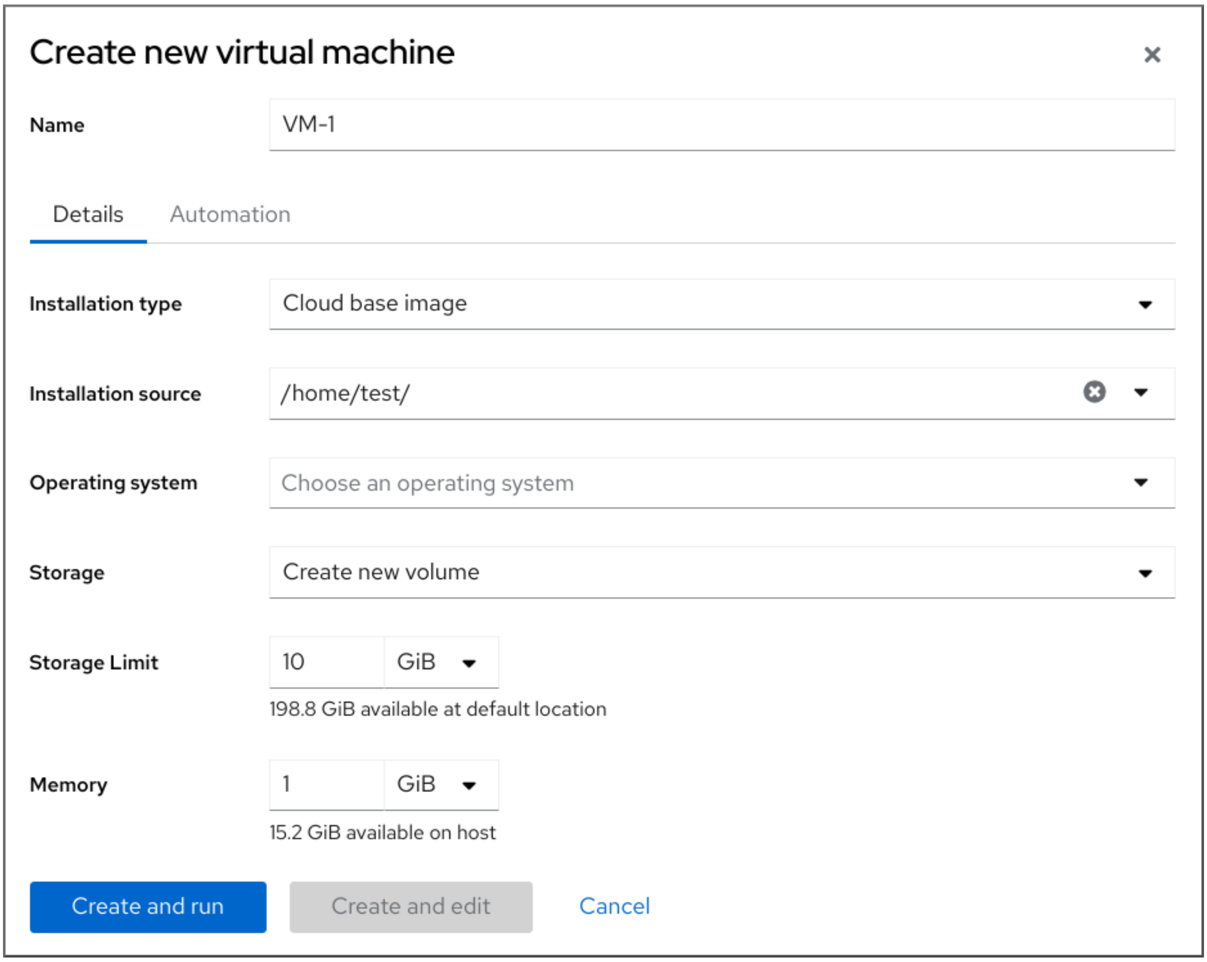
Operating system: Choose an operating system

Storage: Create new volume

Storage limit: 10 GiB

3. In the **Name** field, enter a name for the VM.

4. On the **Details** tab, in the **Installation type** field, select **Cloud base image**



Create new virtual machine

Name: VM-1

Installation type: Cloud base image

Installation source: /home/test/

Operating system: Choose an operating system

Storage: Create new volume

Storage Limit: 10 GiB

198.8 GiB available at default location

Memory: 1 GiB

15.2 GiB available on host

5. In the **Installation source** field, set the path to the image file on your host system.

6. Enter the configuration for the VM that you want to create.

   - **Operating system** - The VM's operating system. Note that Red Hat provides support only for a limited set of guest operating systems .

   - **Storage** - The type of storage with which to configure the VM.

   - **Storage Limit** - The amount of storage space with which to configure the VM.

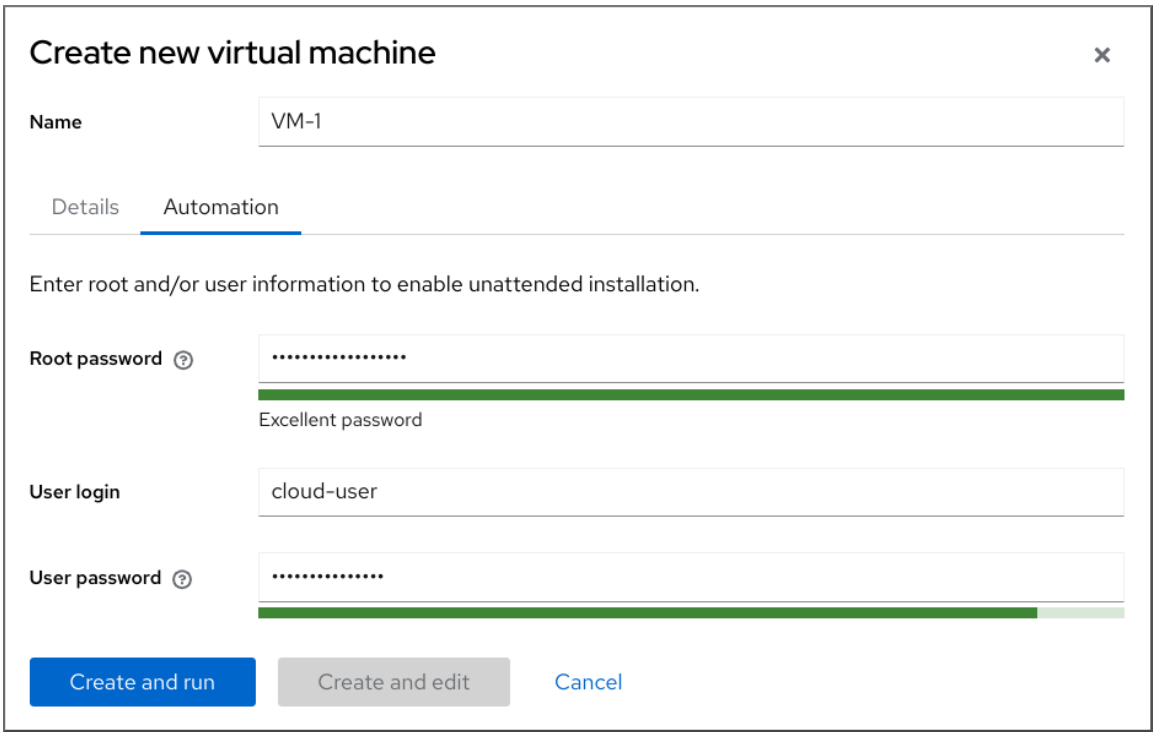
   - **Memory** - The amount of memory with which to configure the VM.

7. Click on the **Automation** tab.
   Set your cloud authentication credentials.

   - **Root password** - Enter a root password for your VM. Leave the field blank if you do not wish to set a root password.

   - **User login** - Enter a cloud-init user login. Leave this field blank if you do not wish to create a user account.

   - **User password** - Enter a password. Leave this field blank if you do not wish to create a user account.



Create new virtual machine

Name: VM-1

Enter root and/or user information to enable unattended installation.

Root password: ••••••••••••••••••

Excellent password

User login: cloud-user

User password: •••••••••••••••

8. Click **Create and run**.
   The VM is created.

Additional resources

- Installing an operating system on a VM

CHAPTER 4. STARTING VIRTUAL MACHINES

To start a virtual machine (VM) in RHEL 9, you can use the command line or the web console GUI.

Prerequisites

- Before a VM can be started, it must be created and, ideally, also installed with an OS. For instruction to do so, see Creating virtual machines.

4.1. STARTING A VIRTUAL MACHINE BY USING THE COMMAND LINE

You can use the command line (CLI) to start a shut-down virtual machine (VM) or restore a saved VM. By using the CLI, you can start both local and remote VMs.

Prerequisites

- An inactive VM that is already defined.
- The name of the VM.
- For remote VMs:
  - The IP address of the host where the VM is located.
  - Root access privileges to the host.

Procedure

- For a local VM, use the **virsh start** utility.
  For example, the following command starts the *demo-guest1* VM.

  ```
  # virsh start demo-guest1
  Domain 'demo-guest1' started
  ```

- For a VM located on a remote host, use the **virsh start** utility along with the QEMU+SSH connection to the host.
  For example, the following command starts the *demo-guest1* VM on the 192.0.2.1 host.

  ```
  # virsh -c qemu+ssh://root@192.0.2.1/system start demo-guest1

  root@192.0.2.1's password:

  Domain 'demo-guest1' started
  ```

Additional resources

- The **virsh start --help** command
- Setting up easy access to remote virtualization hosts
- Starting virtual machines automatically when the host starts

4.2. STARTING VIRTUAL MACHINES BY USING THE WEB CONSOLE

If a virtual machine (VM) is in the *shut off* state, you can start it by using the RHEL 9 web console. You can also configure the VM to be started automatically when the host starts.

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 web console VM plug-in is installed on your system.
- An inactive VM that is already defined.
- The name of the VM.

Procedure

1. In the **Virtual Machines** interface, click the VM you want to start.
   A new page opens with detailed information about the selected VM and controls for shutting down and deleting the VM.
2. Click **Run**.
   The VM starts, and you can connect to its console or graphical output .
3. Optional: To configure the VM to start automatically when the host starts, toggle the **Autostart** checkbox in the **Overview** section.
   If you use network interfaces that are not managed by libvirt, you must also make additional changes to the systemd configuration. Otherwise, the affected VMs might fail to start, see starting virtual machines automatically when the host starts .

Additional resources

- Shutting down virtual machines in the web console
- Restarting virtual machines by using the web console

4.3. STARTING VIRTUAL MACHINES AUTOMATICALLY WHEN THE HOST STARTS

When a host with a running virtual machine (VM) restarts, the VM is shut down, and must be started again manually by default. To ensure a VM is active whenever its host is running, you can configure the VM to be started automatically.

Prerequisites

- A created virtual machine

Procedure

1. Use the **virsh autostart** utility to configure the VM to start automatically when the host starts.
   For example, the following command configures the *demo-guest1* VM to start automatically.

```
# virsh autostart demo-guest1
Domain 'demo-guest1' marked as autostarted
```

2. If you use network interfaces that are not managed by **libvirt**, you must also make additional changes to the systemd configuration. Otherwise, the affected VMs might fail to start.

   NOTE

   These interfaces include for example:

   - Bridge devices created by **NetworkManager**
   - Networks configured to use **<forward mode='bridge'/>**

   a. In the systemd configuration directory tree, create a **virtqemud.service.d** directory if it does not exist yet.

   ```
   # mkdir -p /etc/systemd/system/virtqemud.service.d/
   ```

   b. Create a **10-network-online.conf** systemd unit override file in the previously created directory. The content of this file overrides the default systemd configuration for the **virtqemud** service.

   ```
   # touch /etc/systemd/system/virtqemud.service.d/10-network-online.conf
   ```

   c. Add the following lines to the **10-network-online.conf** file. This configuration change ensures systemd starts the **virtqemud** service only after the network on the host is ready.

   ```
   [Unit]
   After=network-online.target
   ```

Verification

1. View the VM configuration, and check that the *autostart* option is enabled.
   For example, the following command displays basic information about the *demo-guest1* VM, including the *autostart* option.

```
# virsh dominfo demo-guest1
Id:             2
Name:           demo-guest1
UUID:           e46bc81c-74e2-406e-bd7a-67042bae80d1
OS Type:        hvm
State:          running
CPU(s):         2
CPU time:       385.9s
Max memory:     4194304 KiB
Used memory:    4194304 KiB
Persistent:     yes
Autostart:      enable
Managed save:   no
Security model: selinux
Security DOI:   0
Security label: system_u:system_r:svirt_t:s0:c873,c919 (enforcing)
```

2. If you use network interfaces that are not managed by libvirt, check if the content of the **10-network-online.conf** file matches the following output.

```
$ cat /etc/systemd/system/virtqemud.service.d/10-network-online.conf
[Unit]
After=network-online.target
```

Additional resources

- The **virsh autostart --help** command
- Starting virtual machines by using the web console .

CHAPTER 5. CONNECTING TO VIRTUAL MACHINES

To interact with a virtual machine (VM) in RHEL 9, you need to connect to it by doing one of the following:

- When using the web console interface, use the Virtual Machines pane in the web console interface. For more information, see Interacting with virtual machines by using the web console .
- If you need to interact with a VM graphical display without using the web console, use the Virt Viewer application. For details, see Opening a virtual machine graphical console by using Virt Viewer.
- When a graphical display is not possible or not necessary, use an SSH terminal connection .
- When the virtual machine is not reachable from your system by using a network, use the virsh console.

If the VMs to which you are connecting are on a remote host rather than a local one, you can optionally configure your system for more convenient access to remote hosts .

Prerequisites

- The VMs you want to interact with are installed and started.

5.1. INTERACTING WITH VIRTUAL MACHINES BY USING THE WEB CONSOLE

To interact with a virtual machine (VM) in the RHEL 9 web console, you need to connect to the VM's console. These include both graphical and serial consoles.

- To interact with the VM's graphical interface in the web console, use the graphical console.
- To interact with the VM's graphical interface in a remote viewer, use the graphical console in remote viewers.
- To interact with the VM's CLI in the web console, use the serial console.

5.1.1. Viewing the virtual machine graphical console in the web console

By using the virtual machine (VM) console interface, you can view the graphical output of a selected VM 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 .
- The web console VM plug-in is installed on your system.
- Ensure that both the host and the VM support a graphical interface.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. In the **Virtual Machines** interface, click the VM whose graphical console you want to view.
   A new page opens with an **Overview** and a **Console** section for the VM.

3. Select **VNC console** in the console drop down menu.
   The VNC console appears below the menu in the web interface.

   The graphical console appears in the web interface.

4. Click **Expand**
   You can now interact with the VM console by using the mouse and keyboard in the same manner you interact with a real machine. The display in the VM console reflects the activities being performed on the VM.

NOTE

The host on which the web console is running may intercept specific key combinations, such as **Ctrl**+**Alt**+**Del**, preventing them from being sent to the VM.

To send such key combinations, click the **Send key** menu and select the key sequence to send.

For example, to send the **Ctrl**+**Alt**+**Del** combination to the VM, click the **Send key** and select the **Ctrl+Alt+Del** menu entry.

Troubleshooting

- If clicking in the graphical console does not have any effect, expand the console to full screen. This is a known issue with the mouse cursor offset.

Additional resources

- Viewing the graphical console in a remote viewer by using the web console
- Viewing the virtual machine serial console in the web console

5.1.2. Viewing the graphical console in a remote viewer by using the web console

By using the web console interface, you can display the graphical console of a selected virtual machine (VM) in a remote viewer, such as Virt Viewer.

NOTE

You can launch Virt Viewer from within the web console. Other VNC remote viewers can be launched manually.

Prerequisites

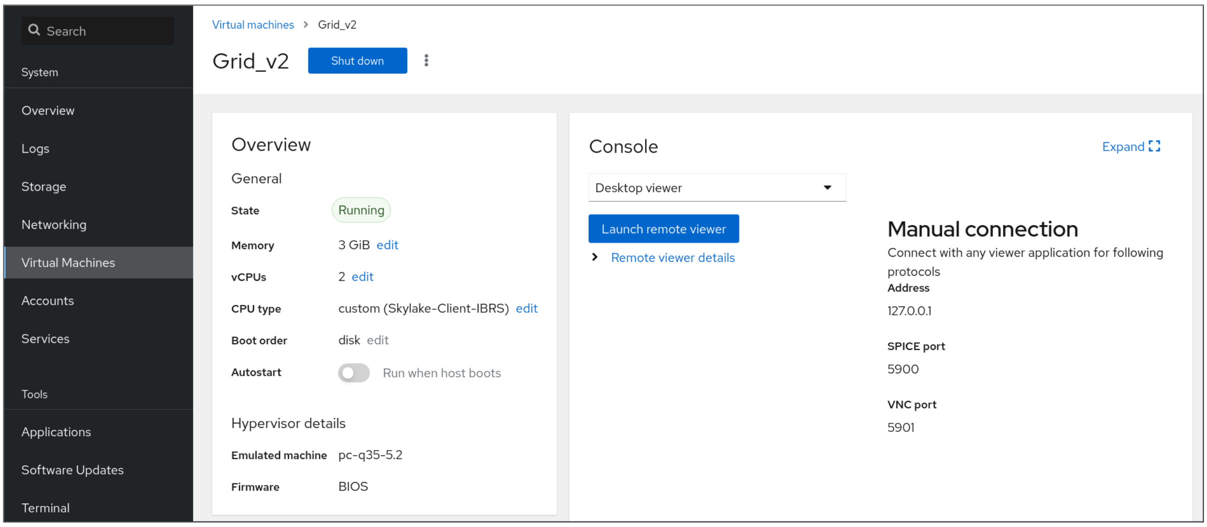
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.

- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The web console VM plug-in is installed on your system .
- Ensure that both the host and the VM support a graphical interface.
- Before you can view the graphical console in Virt Viewer, you must install Virt Viewer on the machine to which the web console is connected.
  1. Click **Launch remote viewer**.
     The virt viewer, **.vv**, file downloads.
  2. Open the file to launch Virt Viewer.

> **NOTE**
>
> Remote Viewer is available on most operating systems. However, some browser extensions and plug-ins do not allow the web console to open Virt Viewer.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the VM whose graphical console you want to view.
   A new page opens with an **Overview** and a **Console** section for the VM.
3. Select **Desktop Viewer** in the console drop down menu.



State: Running
Memory: 3 GiB edit
vCPUs: 2 edit
CPU type: custom (Skylake-Client-IBRS) edit
Boot order: disk edit
Autostart: Run when host boots
Emulated machine: pc-q35-5.2
Firmware: BIOS

Address: 127.0.0.1
SPICE port: 5900
VNC port: 5901

4. Click **Launch Remote Viewer**.
   The graphical console opens in Virt Viewer.

   You can interact with the VM console by using the mouse and keyboard in the same manner in which you interact with a real machine. The display in the VM console reflects the activities being performed on the VM.

NOTE

The server on which the web console is running can intercept specific key combinations, such as **Ctrl**+**Alt**+**Del**, preventing them from being sent to the VM.

To send such key combinations, click the **Send key** menu and select the key sequence to send.

For example, to send the **Ctrl**+**Alt**+**Del** combination to the VM, click the **Send key** menu and select the **Ctrl+Alt+Del** menu entry.

Troubleshooting

- If clicking in the graphical console does not have any effect, expand the console to full screen. This is a known issue with the mouse cursor offset.
- If launching the Remote Viewer in the web console does not work or is not optimal, you can manually connect with any viewer application by using the following protocols:
  - **Address** - The default address is **127.0.0.1**. You can modify the **vnc_listen** parameter in **/etc/libvirt/qemu.conf** to change it to the host's IP address.
  - **VNC port** - 5901

Additional resources

- Viewing the virtual machine graphical console in the web console
- Viewing the virtual machine serial console in the web console

5.1.3. Viewing the virtual machine serial console in the web console

You can view the serial console of a selected virtual machine (VM) in the RHEL 9 web console. This is useful when the host machine or the VM is not configured with a graphical interface.

For more information about the serial console, see Opening a virtual machine serial console .

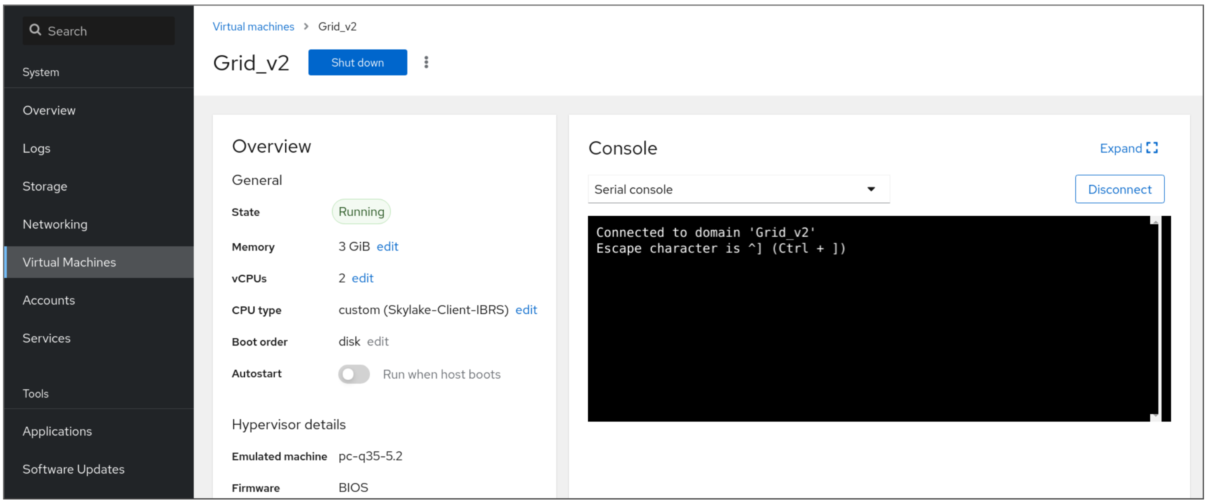
Prerequisites

- 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 web console VM plug-in 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 **Virtual Machines** pane, click the VM whose serial console you want to view.
   A new page opens with an **Overview** and a **Console** section for the VM.

3. Select **Serial console** in the console drop down menu.
   The graphical console appears in the web interface.



State: Running
Memory: 3 GiB edit
vCPUs: 2 edit
CPU type: custom (Skylake-Client-IBRS) edit
Boot order: disk edit
Autostart: Run when host boots
Emulated machine: pc-q35-5.2
Firmware: BIOS

```
Connected to domain 'Grid_v2'
Escape character is ^] (Ctrl + ])
```

You can disconnect and reconnect the serial console from the VM.

- To disconnect the serial console from the VM, click **Disconnect**.
- To reconnect the serial console to the VM, click **Reconnect**.

Additional resources

- Viewing the virtual machine graphical console in the web console
- Viewing the graphical console in a remote viewer by using the web console

5.1.4. Replacing the SPICE remote display protocol with VNC in the web console

The support for the SPICE remote display protocol has been removed on RHEL 9 hosts. If you have a virtual machine (VM) that is configured to use the SPICE protocol, you can replace the SPICE protocol with the VNC protocol by using the web console. Otherwise, the VM fails to start.

However, certain SPICE devices, such as audio and USB passthrough, will be removed from the VM because they do not have a suitable replacement in the VNC protocol. For more information, see Considerations in adopting RHEL 9 .

IMPORTANT

By default, RHEL 8 VMs are configured to use the SPICE protocol. On a RHEL 9 host, these VMs fail to start, if you do not switch from SPICE to VNC.

Prerequisites

- The web console VM plug-in is installed on your system .
- You have an existing VM that is configured to use the SPICE remote display protocol and is already shut-down.

Procedure

1. In the Virtual Machines interface of the web console, click the Menu button ⋮ of the VM that is configured to use the SPICE protocol.
   A drop down menu opens with controls for various VM operations.

2. Click **Replace SPICE devices**.
   The **Replace SPICE devices** dialog opens.

   NOTE

   If you have multiple existing VMs that use the SPICE protocol, they are listed in this dialog. Here, you can select multiple VMs to convert from using SPICE to VNC in a single step.

3. Click **Replace**.
   A confirmation of the successful operation appears.

Verification

1. Click the **Run** button to start the VM.

2. Open the VM overview interface.
   If a **VNC console** option displays in the **Console** pane of the interface, the conversion has been successful.

Additional resources

- Replacing the SPICE remote display protocol with VNC by using the command line

5.2. OPENING A VIRTUAL MACHINE GRAPHICAL CONSOLE BY USING VIRT VIEWER

To connect to a graphical console of a KVM virtual machine (VM) and open it in the **Virt Viewer** desktop application, follow the procedure below.

Prerequisites

- Your system, as well as the VM you are connecting to, must support graphical displays.

- If the target VM is located on a remote host, connection and root access privileges to the host are needed.

- Optional: If the target VM is located on a remote host, set up your libvirt and SSH for more convenient access to remote hosts.

Procedure

- To connect to a local VM, use the following command and replace *guest-name* with the name of the VM you want to connect to:

  ```
  # virt-viewer guest-name
  ```

- To connect to a remote VM, use the **virt-viewer** command with the SSH protocol. For example, the following command connects as root to a VM called *guest-name*, located on remote system 192.0.2.1. The connection also requires root authentication for 192.0.2.1.

  ```
  # virt-viewer --direct --connect qemu+ssh://root@192.0.2.1/system guest-name
  root@192.0.2.1's password:
  ```

Verification

If the connection works correctly, the VM display is shown in the **Virt Viewer** window.

You can interact with the VM console by using the mouse and keyboard in the same manner you interact with a real machine. The display in the VM console reflects the activities being performed on the VM.

Troubleshooting

- If clicking in the graphical console does not have any effect, expand the console to full screen. This is a known issue with the mouse cursor offset.

Additional resources

- **virt-viewer** man page on your system
- Setting up easy access to remote virtualization hosts
- Interacting with virtual machines by using the web console

5.3. CONNECTING TO A VIRTUAL MACHINE BY USING SSH

To interact with the terminal of a virtual machine (VM) by using the SSH connection protocol, follow the procedure below.

Prerequisites

- You have network connection and root access privileges to the target VM.
- If the target VM is located on a remote host, you also have connection and root access privileges to that host.
- Your VM network assigns IP addresses by **dnsmasq** generated by **libvirt**. This is the case for example in **libvirt** NAT networks.
  Notably, if your VM is using one of the following network configurations, you cannot connect to the VM by using SSH:
  - **hostdev** interfaces
  - Direct interfaces
  - Bridge interaces
- The **libvirt-nss** component is installed and enabled on the VM's host. If it is not, do the following:
  a. Install the **libvirt-nss** package:

```
# dnf install libvirt-nss
```

b. Edit the **/etc/nsswitch.conf** file and add **libvirt_guest** to the **hosts** line:

```
...
passwd:      compat
shadow:      compat
group:       compat
hosts:       files libvirt_guest dns
...
```

Procedure

1. When connecting to a remote VM, SSH into its physical host first. The following example demonstrates connecting to a host machine **192.0.2.1** by using its root credentials:

```
# ssh root@192.0.2.1
root@192.0.2.1's password:
Last login: Mon Sep 24 12:05:36 2021
root~#
```

2. Use the VM's name and user access credentials to connect to it. For example, the following connects to the **testguest1** VM by using its root credentials:

```
# ssh root@testguest1
root@testguest1's password:
Last login: Wed Sep 12 12:05:36 2018
root~]#
```

Troubleshooting

- If you do not know the VM's name, you can list all VMs available on the host by using the **virsh list --all** command:

```
# virsh list --all
Id    Name                          State
----------------------------------------------------
2     testguest1                    running
-     testguest2                    shut off
```

Additional resources

- Upstream libvirt documentation

5.4. OPENING A VIRTUAL MACHINE SERIAL CONSOLE

By using the **virsh console** command, it is possible to connect to the serial console of a virtual machine (VM).

This is useful when the VM:

- Does not provide VNC protocols, and thus does not offer video display for GUI tools.

- Does not have a network connection, and thus cannot be interacted with using SSH.

Prerequisites

- The GRUB boot loader on your host must be configured to use serial console. To verify, check that the **/etc/default/grub** file on your host contains the **GRUB_TERMINAL=serial** parameter.

  ```
  $ sudo grep GRUB_TERMINAL /etc/default/grub
  GRUB_TERMINAL=serial
  ```

- The VM must have a serial console device configured, such as **console type='pty'**. To verify, do the following:

  ```
  # virsh dumpxml vm-name | grep console

  <console type='pty' tty='/dev/pts/2'>
  </console>
  ```

- The VM must have the serial console configured in its kernel command line. To verify this, the **cat /proc/cmdline** command output on the VM should include *console=<console-name>*, where *<console-name>* is architecture-specific:

  - For AMD64 and Intel 64: **ttyS0**
  - For ARM 64: **ttyAMA0**

    NOTE

    The following commands in this procedure use **ttyS0**.

    ```
    # cat /proc/cmdline
    BOOT_IMAGE=/vmlinuz-3.10.0-948.el7.x86_64 root=/dev/mapper/rhel-root ro
    console=tty0 console=ttyS0,9600n8 rd.lvm.lv=rhel/root rd.lvm.lv=rhel/swap rhgb
    ```

    If the serial console is not set up properly on a VM, using **virsh console** to connect to the VM connects you to an unresponsive guest console. However, you can still exit the unresponsive console by using the **Ctrl+]** shortcut.

  - To set up serial console on the VM, do the following:

    i. On the VM, enable the **console=ttyS0** kernel option:

    ```
    # grubby --update-kernel=ALL --args="console=ttyS0"
    ```

    ii. Clear the kernel options that might prevent your changes from taking effect.

    ```
    # grub2-editenv - unset kernelopts
    ```

    iii. Reboot the VM.

- The **serial-getty@*<console-name>*** service must be enabled. For example, on AMD64 and Intel 64:

```
# systemctl status serial-getty@ttyS0.service

○ serial-getty@ttyS0.service - Serial Getty on ttyS0
    Loaded: loaded (/usr/lib/systemd/system/serial-getty@.service; enabled; preset: enabled)
```

Procedure

1. On your host system, use the **virsh console** command. The following example connects to the *guest1* VM, if the libvirt driver supports safe console handling:

   ```
   # virsh console guest1 --safe
   Connected to domain 'guest1'
   Escape character is ^]

   Subscription-name
   Kernel 3.10.0-948.el7.x86_64 on an x86_64

   localhost login:
   ```

2. You can interact with the virsh console in the same way as with a standard command-line interface.

Additional resources

- **virsh** man page on your system
- Configuring Serial Console Logs on a VM (video)

5.5. SETTING UP EASIER ACCESS TO REMOTE VIRTUALIZATION HOSTS

When managing VMs on a remote host system by using libvirt utilities, it is recommended to use the **-c qemu+ssh://root@hostname/system** syntax. For example, to use the **virsh list** command as root on the **192.0.2.1** host:

```
# virsh -c qemu+ssh://root@192.0.2.1/system list
root@192.0.2.1's password:

Id   Name              State
---------------------------------
1    remote-guest      running
```

However, you can remove the need to specify the connection details in full by modifying your SSH and libvirt configuration. For example:

```
# virsh -c remote-host list
root@192.0.2.1's password:

Id   Name              State
---------------------------------
1    remote-guest      running
```

To enable this improvement, follow the instructions below.

Procedure

1. Edit the **~/.ssh/config** file with the following details, where *host-alias* is a shortened name associated with a specific remote host and an alias for root@192.0.2.1, and *hosturl* is the URL address of the host :

   ```
   # vi ~/.ssh/config
   Host example-host-alias
     User                  root
     Hostname              192.0.2.1
   ```

2. Edit the **/etc/libvirt/libvirt.conf** file with the following details, the *example-qemu-host-alias* is a host alias that QEMU and libvirt utilities will associate for **qemu+ssh://192.0.2.1/system** with the intended host *example-host-alias* :

   ```
   # vi /etc/libvirt/libvirt.conf
   uri_aliases = [
     "example-qemu-host-alias=qemu+ssh://example-host-alias/system",
   ]
   ```

Verification

1. Confirm that you can manage remote VMs by using libvirt-based utilities on the local system with an added **-c *qemu-host-alias*** parameter. This automatically performs the commands over SSH on the remote host.
   For example, verify that the following lists VMs on the 192.0.2.1 remote host, the connection to which was set up as *example-qemu-host-alias* in the previous steps:

   ```
   # virsh -c example-qemu-host-alias list

   root@192.0.2.1's password:

   Id   Name                     State
   ----------------------------------------
   1    example-remote-guest     running
   ```

NOTE

In addition to **virsh**, the **-c** (or **--connect**) option and the remote host access configuration described above can be used by the following utilities:

- virt-install
- virt-viewer

Next steps

If you want to use libvirt utilities exclusively on a single remote host, you can also set a specific connection as the default target for libvirt-based utilities. However, this is not recommended if you also want to manage VMs on your local host or on different remote hosts.

- You can edit the **/etc/libvirt/libvirt.conf** file and set the value of the **uri_default** parameter to *example-qemu-host-alias* as a default libvirt target.

```
# These can be used in cases when no URI is supplied by the application
# (@uri_default also prevents probing of the hypervisor driver).
#
uri_default = "example-qemu-host-alias"
```

As a result, all libvirt-based commands will automatically be performed on the specified remote host.

```
$ virsh list
root@192.0.2.1's password:

Id   Name              State
---------------------------------
1    example-remote-guest      running
```

- When connecting to a remote host, you can avoid providing the root password to the remote system. To do so, use one or more of the following methods:
  - Set up key-based SSH access to the remote host
  - Use SSH connection multiplexing to connect to the remote system **Logging in to IdM in the Web UI: Using a Kerberos ticket
- The **-c** (or **--connect**) option can be used to run the **virt-install**,

virt-viewer, and **virsh** commands on a remote host.

5.6. REPLACING THE SPICE REMOTE DISPLAY PROTOCOL WITH VNC BY USING THE COMMAND LINE

The support for the SPICE remote display protocol has been removed on RHEL 9 hosts. If you have a virtual machine (VM) that is configured to use the SPICE protocol, you can replace the SPICE protocol with the VNC protocol by using the command line. Otherwise, the VM fails to start.

However, certain SPICE devices, such as audio and USB passthrough, will be removed from the VM because they do not have a suitable replacement in the VNC protocol. For more information, see Considerations in adopting RHEL 9 .

IMPORTANT

By default, RHEL 8 VMs are configured to use the SPICE protocol. On a RHEL 9 host, these VMs fail to start, if you do not switch from SPICE to VNC.

Prerequisites

- You have an existing VM that is configured to use the SPICE remote display protocol and is already shut-down.

Procedure

- On the host, run the following command, and replace `*<vm-name>*` with the name of the VM that you want to convert to VNC.

```
# virt-xml <vm-name> --edit --convert-to-vnc

Domain 'vm-name' defined successfully
```

Verification

- Inspect the configuration of the VM you converted, and make sure the graphics type is listed as **vnc**.

  ```
  # virsh dumpxml -xml <vm-name> | grep "graphics"

  <graphics type='vnc' port='5900' autoport='yes' listen='127.0.0.1'>
  ```

Additional resources

- Replacing the SPICE remote display protocol with VNC in the web console

5.7. CONFIGURING VNC PASSWORDS

To manage access to the graphical output of a virtual machine (VM), you can configure a password for the VNC console of the VM.

With a VNC password configured on a VM, users of the VMs must enter the password when attempting to view or interact with the VNC graphical console of the VMs, for example by using the **virt-viewer** utility.

> **IMPORTANT**
>
> VNC passwords are not a sufficient measure for ensuring the security of a VM environment. For details, see QEMU documentation on VNC security.
>
> In addition, the VNC password is saved in plain text in the configuration of the VM, so for the password to be effective, the user must not be able to display the VM configuration.

Prerequisites

- The VM that you want to protect with a VNC password has VNC graphics configured.
  To ensure that this is the case, use the **virsh dumpxml** command as follows:

  ```
  # virsh dumpxml <vm-name> | grep graphics

   <graphics type='vnc' ports='-1' autoport=yes listen=127.0.0.1>
   </graphics>
  ```

Procedure

1. Open the configuration of the VM that you want to assign a VNC password to.

   ```
   # virsh edit <vm-name>
   ```

2. On the **<graphics>** line of the configuration, add the **passwd** attribute and the password string. The password must be 8 characters or fewer.

```
<graphics type='vnc' ports='-1' autoport=yes listen=127.0.0.1 passwd='<password>'>
```

- Optional: In addition, define a date and time when the password will expire.

  ```
   <graphics type='vnc' ports='-1' autoport=yes listen=127.0.0.1 passwd='<password>'
  passwdValidTo='2025-02-01T15:30:00'>
  ```

  In this example, the password will expire on February 1st 2025, at 15:30 UTC.

3. Save the configuration.

Verification

1. Start the modified VM.

   ```
   # virsh start <vm-name>
   ```

2. Open a graphical console of the VM, for example by using the **virt-viewer** utility:

   ```
   # virt-viewer <vm-name>
   ```

   If the VNC password has been configured properly, a dialogue window appears that requests you to enter the password.

CHAPTER 6. SHUTTING DOWN VIRTUAL MACHINES

To shut down a running virtual machine hosted on RHEL 9, use the command line or the web console GUI.

6.1. SHUTTING DOWN A VIRTUAL MACHINE BY USING THE COMMAND LINE

Shutting down a virtual machine (VM) requires different steps based on whether the VM is reponsive.

Shutting down a responsive VM

- If you are connected to the guest , use a shutdown command or a GUI element appropriate to the guest operating system.

  > **NOTE**
  >
  > In some environments, such as in Linux guests that use the GNOME Desktop, using the GUI power button for suspending or hibernating the guest might instead shut down the VM.

- Alternatively, use the **virsh shutdown** command on the host:
  - If the VM is on a local host:

    ```
    # virsh shutdown demo-guest1
    Domain 'demo-guest1' is being shutdown
    ```

  - If the VM is on a remote host, in this example *192.0.2.1*:

    ```
    # virsh -c qemu+ssh://root@192.0.2.1/system shutdown demo-guest1

    root@192.0.2.1's password:
    Domain 'demo-guest1' is being shutdown
    ```

Shutting down an unresponsive VM

To force a VM to shut down, for example if it has become unresponsive, use the **virsh destroy** command on the host:

```
# virsh destroy demo-guest1
Domain 'demo-guest1' destroyed
```

> **NOTE**
>
> The **virsh destroy** command does not actually delete or remove the VM configuration or disk images. It only terminates the running instance of the VM, similarly to pulling the power cord from a physical machine.
>
> In rare cases, **virsh destroy** may cause corruption of the VM's file system, so using this command is only recommended if all other shutdown methods have failed.

Verification

- On the host, display the list of your VMs to see their status.

```
# virsh list --all

 Id   Name               State
------------------------------------------
 1    demo-guest1         shut off
```

6.2. SHUTTING DOWN AND RESTARTING VIRTUAL MACHINES BY USING THE WEB CONSOLE

Using the RHEL 9 web console, you can shut down or restart running virtual machines. You can also send a non-maskable interrupt to an unresponsive virtual machine.

6.2.1. Shutting down virtual machines in the web console

If a virtual machine (VM) is in the **running** state, you can shut it down by using 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 .
- The web console VM plug-in is installed on your system .

Procedure

1. In the **Virtual Machines** interface, find the row of the VM you want to shut down.
2. On the right side of the row, click **Shut Down**.
   The VM shuts down.

Troubleshooting

- If the VM does not shut down, click the Menu button ⋮ next to the **Shut Down** button and select **Force Shut Down**.
- To shut down an unresponsive VM, you can also send a non-maskable interrupt .

Additional resources

- Starting virtual machines by using the web console
- Restarting virtual machines by using the web console

6.2.2. Restarting virtual machines by using the web console

If a virtual machine (VM) is in the **running** state, you can restart it by using 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 .
- The web console VM plug-in is installed on your system .

Procedure

1. In the **Virtual Machines** interface, find the row of the VM you want to restart.
2. On the right side of the row, click the Menu button ⋮ .
   A drop-down menu of actions appears.
3. In the drop-down menu, click **Reboot**.
   The VM shuts down and restarts.

Troubleshooting

- If the VM does not restart, click the Menu button ⋮ next to the **Reboot** button and select **Force Reboot**.
- To shut down an unresponsive VM, you can also send a non-maskable interrupt .

Additional resources

- Starting virtual machines by using the web console
- Shutting down virtual machines in the web console

6.2.3. Sending non-maskable interrupts to VMs by using the web console

Sending a non-maskable interrupt (NMI) may cause an unresponsive running virtual machine (VM) to respond or shut down. For example, you can send the **Ctrl**+**Alt**+**Del** NMI to a VM that is not responding to standard input.

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 web console VM plug-in 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 **Virtual Machines** interface, find the row of the VM to which you want to send an NMI.

3. On the right side of the row, click the Menu button ⋮ .
   A drop-down menu of actions appears.

4. In the drop-down menu, click **Send non-maskable interrupt**
   An NMI is sent to the VM.

Additional resources

- Starting virtual machines by using the web console
- Restarting virtual machines by using the web console
- Shutting down virtual machines in the web console

CHAPTER 7. DELETING VIRTUAL MACHINES

To delete virtual machines in RHEL 9, use the command line or the web console GUI.

7.1. DELETING VIRTUAL MACHINES BY USING THE COMMAND LINE

To delete a virtual machine (VM), you can remove its XML configuration and associated storage files from the host by using the command line. Follow the procedure below:

Prerequisites

- Back up important data from the VM.
- Shut down the VM.
- Make sure no other VMs use the same associated storage.

Procedure

- Use the **virsh undefine** utility.
  For example, the following command removes the *guest1* VM, its associated storage volumes, and non-volatile RAM, if any.

```
# virsh undefine guest1 --remove-all-storage --nvram
Domain 'guest1' has been undefined
Volume 'vda'(/home/images/guest1.qcow2) removed.
```

Additional resources

- **virsh undefine --help** command
- **virsh** man page on your system

7.2. DELETING VIRTUAL MACHINES BY USING THE WEB CONSOLE

To delete a virtual machine (VM) and its associated storage files from the host to which the RHEL 9 web console is connected with, follow the procedure below:

Prerequisites

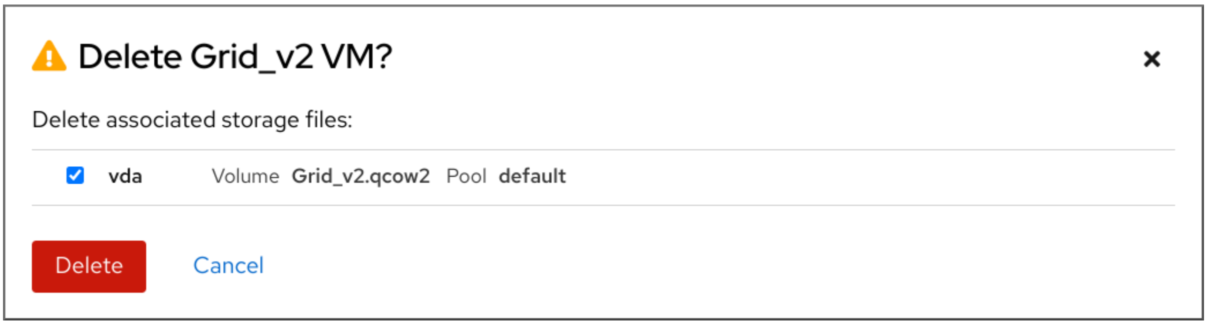
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

- You have installed the 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 web console VM plug-in is installed on your system .
- Back up important data from the VM.
- Make sure no other VM uses the same associated storage.
- Optional: Shut down the VM.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the Menu button ⋮ of the VM that you want to delete.
   A drop down menu appears with controls for various VM operations.
3. Click **Delete**.
   A confirmation dialog appears.



Delete Grid_v2 VM?

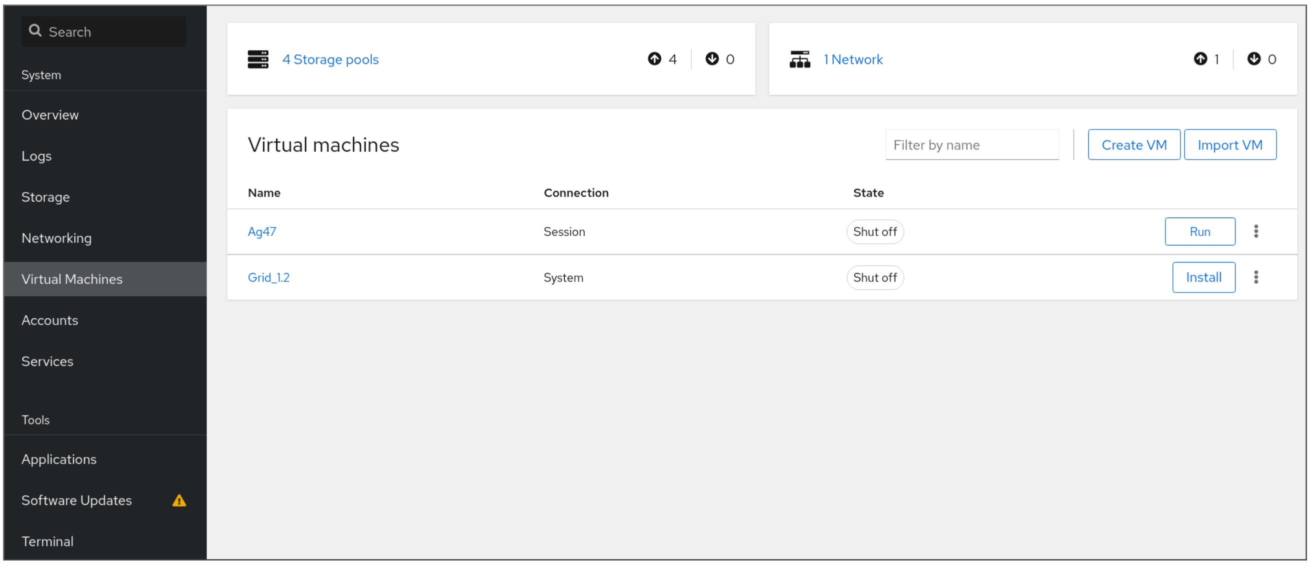
Delete associated storage files:

☑ vda Volume **Grid_v2.qcow2** Pool **default**

4. Optional: To delete all or some of the storage files associated with the VM, select the checkboxes next to the storage files you want to delete.
5. Click **Delete**.
   The VM and any selected storage files are deleted.

CHAPTER 8. MANAGING VIRTUAL MACHINES IN THE WEB CONSOLE

To manage virtual machines in a graphical interface on a RHEL 9 host, you can use the **Virtual Machines** pane in the RHEL 9 web console.



Virtual machines

Name	Connection	State
Ag47	Session	Shut off
Grid_1.2	System	Shut off

8.1. OVERVIEW OF VIRTUAL MACHINE MANAGEMENT BY USING THE WEB CONSOLE

The RHEL 9 web console is a web-based interface for system administration. As one of its features, the web console provides a graphical view of virtual machines (VMs) on the host system, and makes it possible to create, access, and configure these VMs.

Note that to use the web console to manage your VMs on RHEL 9, you must first install a web console plug-in for virtualization.

Next steps

- For instructions on enabling VMs management in your web console, see Setting up the web console to manage virtual machines.
- For a comprehensive list of VM management actions that the web console provides, see Virtual machine management features available in the web console.

8.2. SETTING UP THE WEB CONSOLE TO MANAGE VIRTUAL MACHINES

Before using the RHEL 9 web console to manage virtual machines (VMs), you must install the web console virtual machine plug-in on the host.

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 .

Procedure

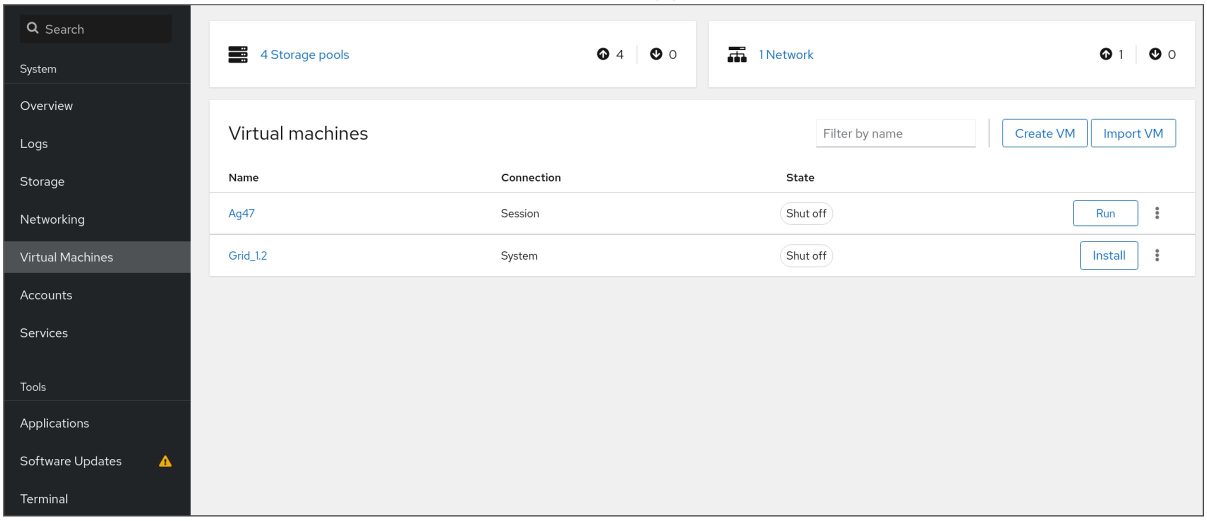
- Install the **cockpit-machines** plug-in.

```
# dnf install cockpit-machines
```

Verification

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. If the installation was successful, **Virtual Machines** appears in the web console side menu.



Name	Connection	State
Ag47	Session	Shut off
Grid_1.2	System	Shut off

Additional resources

- Managing systems by using the RHEL 9 web console

8.3. RENAMING VIRTUAL MACHINES BY USING THE WEB CONSOLE

You might require renaming an existing virtual machine (VM) to avoid naming conflicts or assign a new unique name based on your use case. To rename the VM, you can use the RHEL 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 .

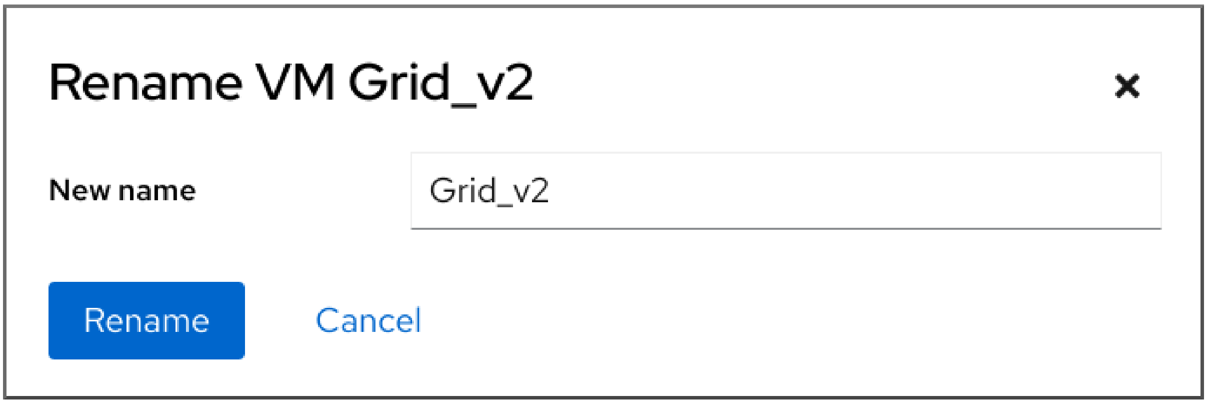
- The web console VM plug-in is installed on your system.

- The VM is shut down.

Procedure

1. In the **Virtual Machines** interface, click the Menu button ⋮ of the VM that you want to rename.
   A drop-down menu appears with controls for various VM operations.

2. Click **Rename**.
   The **Rename a VM** dialog appears.



Rename VM Grid_v2

New name: Grid_v2

3. In the **New name** field, enter a name for the VM.

4. Click **Rename**.

Verification

- Check that the new VM name has appeared in the **Virtual Machines** interface.

8.4. VIRTUAL MACHINE MANAGEMENT FEATURES AVAILABLE IN THE WEB CONSOLE

By using the RHEL 9 web console, you can perform the following actions to manage the virtual machines (VMs) on your system.

Table 8.1. VM management tasks that you can perform in the RHEL 9 web console

Task	For details, see
Create a VM and install it with a guest operating system	Creating virtual machines and installing guest operating systems by using the web console
Delete a VM	Deleting virtual machines by using the web console
Start, shut down, and restart the VM	Starting virtual machines by using the web console and Shutting down and restarting virtual machines by using the web console
Connect to and interact with a VM using a variety of consoles	Interacting with virtual machines by using the web console
View a variety of information about the VM	Viewing virtual machine information by using the web console

Task	For details, see
Manage network connections for the VM	Using the web console for managing virtual machine network interfaces
Manage the VM storage available on the host and attach virtual disks to the VM	Managing storage for virtual machines by using the web console
Configure the virtual CPU settings of the VM	Managing virtal CPUs by using the web console
Live migrate a VM	Live migrating a virtual machine by using the web console
Manage host devices	Managing host devices by using the web console
Manage virtual optical drives	Managing virtual optical drives
Attach watchdog device	Attaching a watchdog device to a virtual machine by using the web console

CHAPTER 9. VIEWING INFORMATION ABOUT VIRTUAL MACHINES

When you need to adjust or troubleshoot any aspect of your virtualization deployment on RHEL 9, the first step you need to perform usually is to view information about the current state and configuration of your virtual machines (VMs). To do so, you can use the command line or the web console. You can also view the information in the VM's XML configuration.

9.1. VIEWING VIRTUAL MACHINE INFORMATION BY USING THE COMMAND LINE

To retrieve information about virtual machines (VMs) on your host and their configurations, use one or more of the following commands.

Procedure

- To obtain a list of VMs on your host:

```
# virsh list --all
Id   Name              State
----------------------------------
1    testguest1             running
-    testguest2            shut off
-    testguest3            shut off
-    testguest4            shut off
```

- To obtain basic information about a specific VM:

```
# virsh dominfo testguest1
Id:             1
Name:           testguest1
UUID:           a973666f-2f6e-415a-8949-75a7a98569e1
OS Type:        hvm
State:          running
CPU(s):         2
CPU time:       188.3s
Max memory:     4194304 KiB
Used memory:    4194304 KiB
Persistent:     yes
Autostart:      disable
Managed save:   no
Security model: selinux
Security DOI:   0
Security label: system_u:system_r:svirt_t:s0:c486,c538 (enforcing)
```

- To obtain the complete XML configuration of a specific VM:

```
# virsh dumpxml testguest2

<domain type='kvm' id='1'>
  <name>testguest2</name>
  <uuid>a973434f-2f6e-4ěša-8949-76a7a98569e1</uuid>
  <metadata>
[...]
```

For an annotated example of a VM's XML configuration, see Sample virtual machine XML configuration

- For information about a VM's disks and other block devices:

```
# virsh domblklist testguest3
 Target   Source
---------------------------------------------------------------
 vda      /var/lib/libvirt/images/testguest3.qcow2
 sda      -
 sdb      /home/username/Downloads/virt-p2v-1.36.10-1.el7.iso
```

For instructions on managing a VM's storage, see Managing storage for virtual machines.

- To obtain information about a VM's file systems and their mountpoints:

```
# virsh domfsinfo testguest3
Mountpoint   Name   Type   Target
------------------------------------
 /            dm-0   xfs
 /boot        vda1   xfs
```

- To obtain more details about the vCPUs of a specific VM:

```
# virsh vcpuinfo testguest4
VCPU:          0
CPU:           3
State:         running
CPU time:      103.1s
CPU Affinity:  yyyy

VCPU:          1
CPU:           0
State:         running
CPU time:      88.6s
CPU Affinity:  yyyy
```

To configure and optimize the vCPUs in your VM, see Optimizing virtual machine CPU performance.

- To list all virtual network interfaces on your host:

```
# virsh net-list --all
 Name       State    Autostart   Persistent
---------------------------------------------
 default    active   yes         yes
 labnet     active   yes         yes
```

For information about a specific interface:

```
# virsh net-info default
```

```
Name:         default
UUID:         c699f9f6-9202-4ca8-91d0-6b8cb9024116
Active:       yes
Persistent:   yes
Autostart:    yes
Bridge:       virbr0
```

For details about network interfaces, VM networks, and instructions for configuring them, see Configuring virtual machine network connections.

- For instructions on viewing information about storage pools and storage volumes on your host, see Viewing virtual machine storage information by using the CLI.

9.2. VIEWING VIRTUAL MACHINE INFORMATION BY USING THE WEB CONSOLE

By using the RHEL 9 web console, you can view information about all VMs and storage pools the web console session can access.

You can view information about a selected VM to which the web console session is connected. This includes information about its disks, virtual network interface and resource usage.

9.2.1. Viewing a virtualization overview in the web console

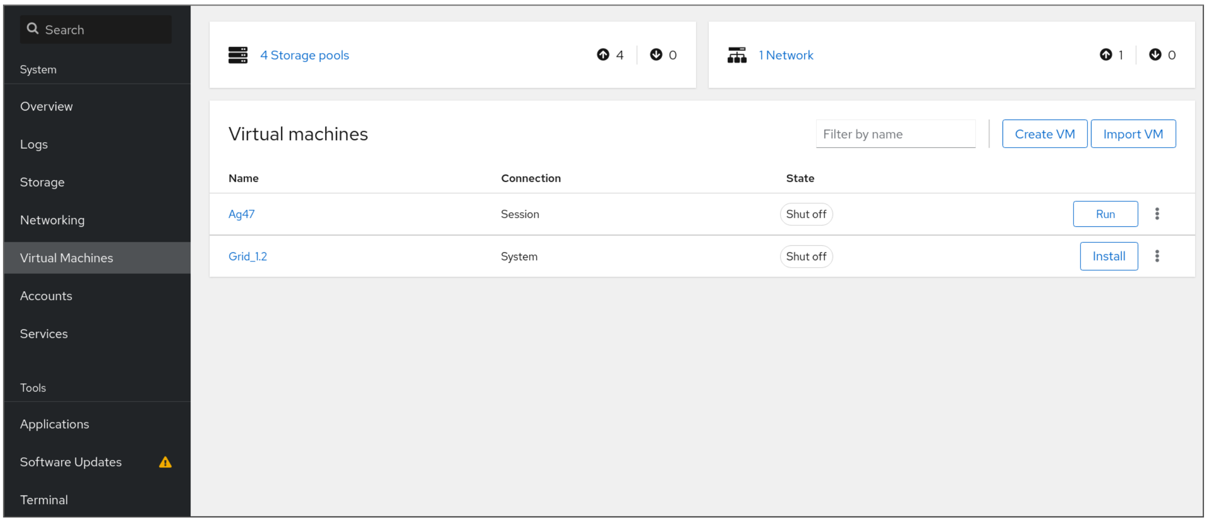
By using the web console, you can access a virtualization overview that contains summarized information about available virtual machines (VMs), storage pools, and networks.

Prerequisites

- The web console VM plug-in is installed on your system.

Procedure

- Click **Virtual Machines** in the web console's side menu.
A dialog box appears with information about the available storage pools, available networks, and the VMs to which the web console is connected.



Virtual machines

Name	Connection	State
Ag47	Session	Shut off
Grid_1.2	System	Shut off

The information includes the following:

- **Storage Pools** - The number of storage pools, active or inactive, that can be accessed by the web console and their state.
- **Networks** - The number of networks, active or inactive, that can be accessed by the web console and their state.
- **Name** - The name of the VM.
- **Connection** - The type of libvirt connection, system or session.
- **State** - The state of the VM.

Additional resources

- Viewing virtual machine information by using the web console

9.2.2. Viewing storage pool information by using the web console

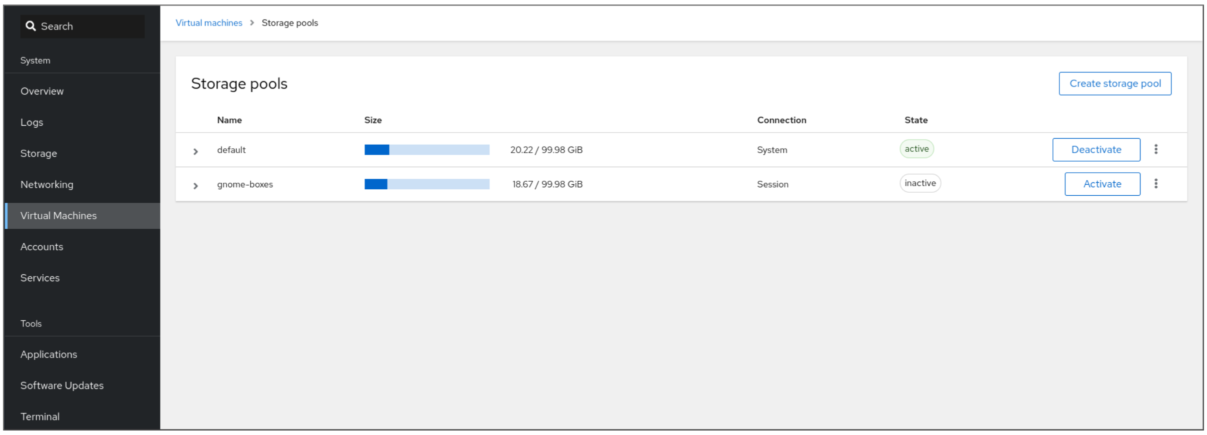
By using the web console, you can view detailed information about storage pools available on your system. Storage pools can be used to create disk images for your virtual machines.

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 web console VM plug-in 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. Click **Storage Pools** at the top of the **Virtual Machines** interface.
   The **Storage pools** window appears, showing a list of configured storage pools.



Storage pools

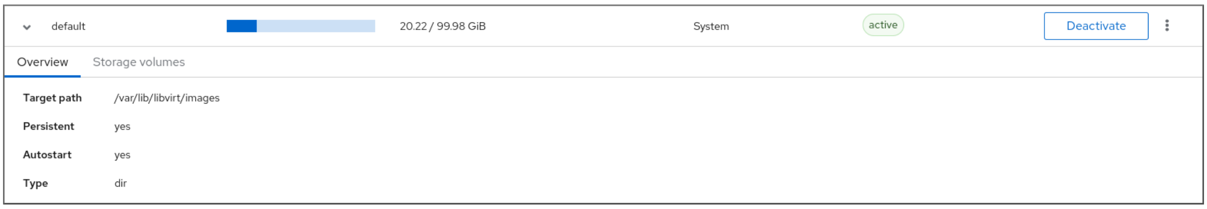
Name	Size	Connection	State
default	20.22 / 99.98 GiB	System	active
gnome-boxes	18.67 / 99.98 GiB	Session	inactive

The information includes the following:

- **Name** - The name of the storage pool.

- **Size** - The current allocation and the total capacity of the storage pool.
- **Connection** - The connection used to access the storage pool.
- **State** - The state of the storage pool.

3. Click the arrow next to the storage pool whose information you want to see.
   The row expands to reveal the Overview pane with detailed information about the selected storage pool.

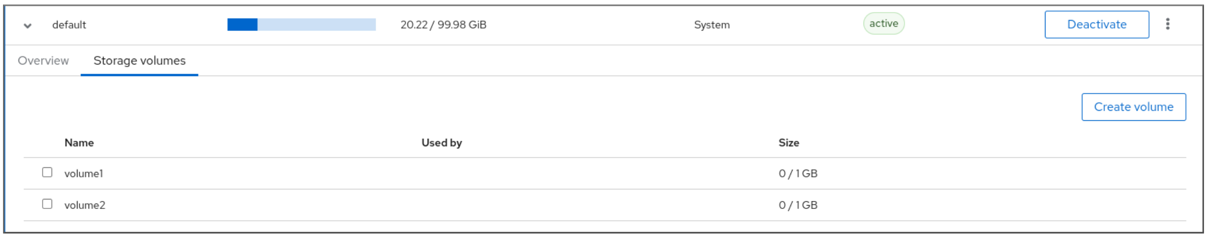


Target path	/var/lib/libvirt/images
Persistent	yes
Autostart	yes
Type	dir

The information includes:

- **Target path** – The location of the storage pool.
- **Persistent** - Indicates whether or not the storage pool has a persistent configuration.
- **Autostart** - Indicates whether or not the storage pool starts automatically when the system boots up.
- **Type** – The type of the storage pool.

4. To view a list of storage volumes associated with the storage pool, click **Storage Volumes**.
   The Storage Volumes pane appears, showing a list of configured storage volumes.



Name	Used by	Size
□ volume1		0 / 1 GB
□ volume2		0 / 1 GB

The information includes:

- **Name** – The name of the storage volume.
- **Used by** – The VM that is currently using the storage volume.
- **Size** – The size of the volume.

Additional resources

- Viewing virtual machine information by using the web console

9.2.3. Viewing basic virtual machine information in the web console

By using the web console, you can view basic information, such as assigned resources or hypervisor details, about a selected virtual machine (VM).

Prerequisites

- The web console VM plug-in 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. Click **Virtual Machines** in the web console side menu.
3. Click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

   The Overview section includes the following general VM details:

   - **State** - The VM state, Running or Shut off.
   - **Memory** - The amount of memory assigned to the VM.
   - **CPU** - The number and type of virtual CPUs configured for the VM.
   - **Boot Order** - The boot order configured for the VM.
   - **Autostart** - Whether or not autostart is enabled for the VM.

   The information also includes the following hypervisor details:

   - **Emulated Machine** - The machine type emulated by the VM.
   - **Firmware** - The firmware of the VM.

Additional resources

- Viewing virtual machine information by using the web console
- Managing virtual CPUs by using the web console

9.2.4. Viewing virtual machine resource usage in the web console

By using the web console, you can view memory and virtual CPU usage of a selected virtual machine (VM).

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 web console VM plug-in is installed on your system.

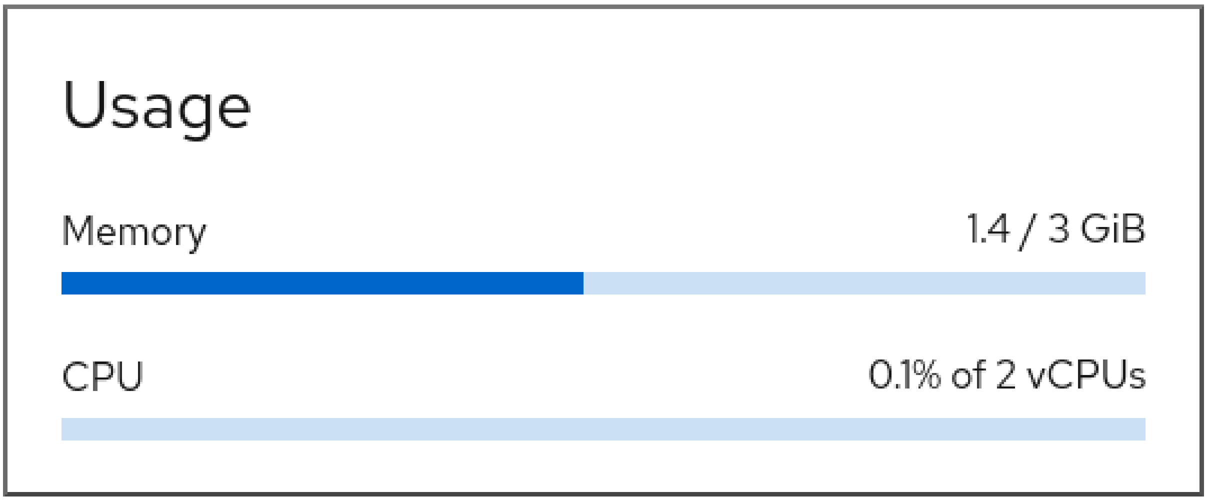
Procedure

1. Log in to the RHEL 9 web console.

For details, see Logging in to the web console .

2. In the **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

3. Scroll to **Usage**.
   The Usage section displays information about the memory and virtual CPU usage of the VM.



Usage

Memory 1.4 / 3 GiB

CPU 0.1% of 2 vCPUs

Additional resources

- Viewing virtual machine information by using the web console

9.2.5. Viewing virtual machine disk information in the web console

By using the web console, you can view detailed information about disks assigned to a selected virtual machine (VM).

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 web console VM plug-in is installed on your system .

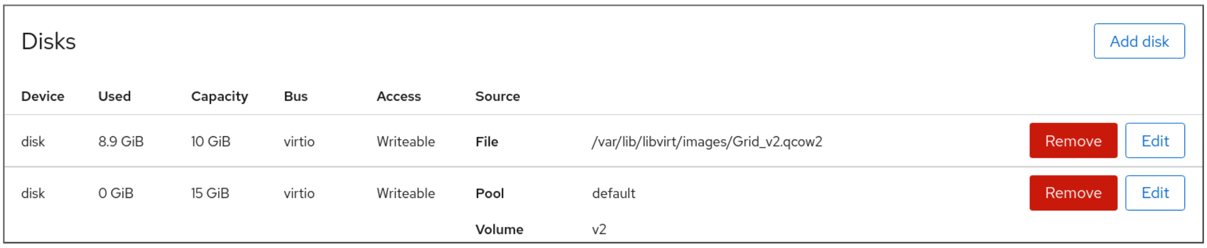
Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. Click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

3. Scroll to **Disks**.

The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.



Device	Used	Capacity	Bus	Access	Source		
disk	8.9 GiB	10 GiB	virtio	Writeable	**File**	/var/lib/libvirt/images/Grid_v2.qcow2	Remove Edit
disk	0 GiB	15 GiB	virtio	Writeable	**Pool** **Volume**	default v2	Remove Edit

The information includes the following:

- **Device** - The device type of the disk.
- **Used** - The amount of disk currently allocated.
- **Capacity** - The maximum size of the storage volume.
- **Bus** - The type of disk device that is emulated.
- **Access** - Whether the disk is **Writeable** or **Read-only**. For **raw** disks, you can also set the access to **Writeable and shared**.
- **Source** - The disk device or file.

Additional resources

- Viewing virtual machine information by using the web console

9.2.6. Viewing and editing virtual network interface information in the web console

By using the RHEL 9 web console, you can view and modify the virtual network interfaces on a selected virtual machine (VM):

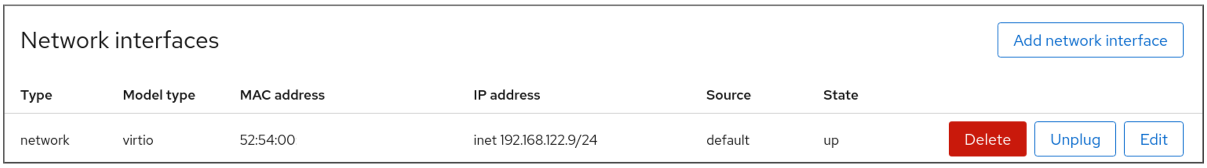
Prerequisites

- 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 web console VM plug-in 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 **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM’s graphical interface.
3. Scroll to **Network Interfaces**.

The Networks Interfaces section displays information about the virtual network interface configured for the VM as well as options to **Add**, **Delete**, **Edit**, or **Unplug** network interfaces.



Network interfaces

Type	Model type	MAC address	IP address	Source	State	
network	virtio	52:54:00	inet 192.168.122.9/24	default	up	Delete Unplug Edit

The information includes the following:

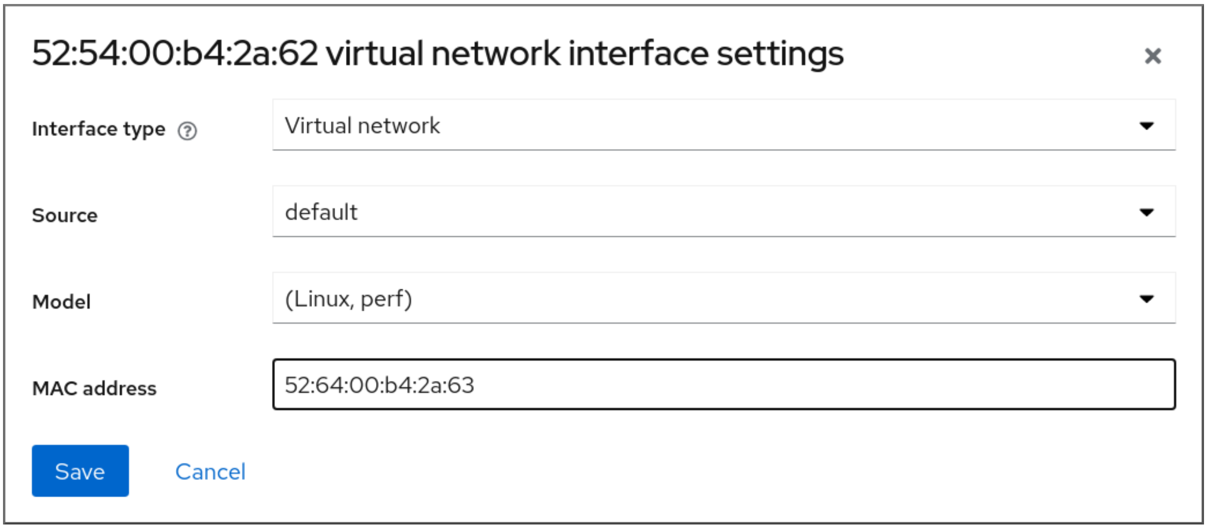
- **Type** - The type of network interface for the VM. The types include virtual network, bridge to LAN, and direct attachment.

  ### NOTE

  Generic Ethernet connection is not supported in RHEL 9 and later.

- **Model type** - The model of the virtual network interface.
- **MAC Address** - The MAC address of the virtual network interface.
- **IP Address** - The IP address of the virtual network interface.
- **Source** - The source of the network interface. This is dependent on the network type.
- **State** - The state of the virtual network interface.

4. To edit the virtual network interface settings, Click **Edit**. The Virtual Network Interface Settings dialog opens.



52:54:00:b4:2a:62 virtual network interface settings

Interface type: Virtual network

Source: default

Model: (Linux, perf)

MAC address: 52:64:00:b4:2a:63

5. Change the interface type, source, model, or MAC address.

6. Click **Save**. The network interface is modified.

NOTE

Changes to the virtual network interface settings take effect only after restarting the VM.

Additionally, MAC address can only be modified when the VM is shut off.

Additional resources

- Viewing virtual machine information by using the web console

9.3. SAMPLE VIRTUAL MACHINE XML CONFIGURATION

The XML configuration of a VM, also referred to as a *domain XML*, determines the VM's settings and components. The following table shows sections of a sample XML configuration of a virtual machine (VM) and explains the contents.

To obtain the XML configuration of a VM, you can use the **virsh dumpxml** command followed by the VM's name.

```
# virsh dumpxml testguest1
```

Table 9.1. Sample XML configuration

Domain XML Section	Description

`<domain type='kvm'>`
` <name>Testguest1</name>`
` <uuid>ec6fbaa1-3eb4-49da-bf61-bb02fbec4967</uuid>`
` <memory unit='KiB'>1048576</memory>`
` <currentMemory unit='KiB'>1048576</currentMemory>`
	This is a KVM virtual machine called *Testguest1*, with 1024 MiB allocated RAM.

` <vcpu placement='static'>1</vcpu>`	The VM is allocated with a single virtual CPU (vCPU). For information about configuring vCPUs, see Optimizing virtual machine CPU performance.

` <os>`
`  <type arch='x86_64' machine='pc-q35-rhel9.0.0'>hvm</type>`
`  <boot dev='hd'/>`
` </os>`
	The machine architecture is set to the AMD64 and Intel 64 architecture, and uses the Intel Q35 machine type to determine feature compatibility. The OS is set to be booted from the hard disk drive.
	For information about creating a VM with an installed OS, see Creating virtual machines and installing guest operating systems by using the web console.

` <features>`
`  <acpi/>`
`  <apic/>`
` </features>`
	The **acpi** and **apic** hypervisor features are enabled.

Domain XML Section	Description
<cpu mode='host-model' check='partial'/>	The host CPU definitions from capabilities XML (obtainable with **virsh domcapabilities**) are automatically copied into the VM's XML configuration. Therefore, when the VM is booted, **libvirt** picks a CPU model that is similar to the host CPU, and then adds extra features to approximate the host model as closely as possible.
<clock offset='utc'> <timer name='rtc' tickpolicy='catchup'/> <timer name='pit' tickpolicy='delay'/> <timer name='hpet' present='no'/> </clock>	The VM's virtual hardware clock uses the UTC time zone. In addition, three different timers are set up for synchronization with the QEMU hypervisor.
<on_poweroff>destroy</on_poweroff> <on_reboot>restart</on_reboot> <on_crash>destroy</on_crash>	When the VM powers off, or its OS terminates unexpectedly, **libvirt** terminates the VM and releases all its allocated resources. When the VM is rebooted, **libvirt** restarts it with the same configuration.
<pm> <suspend-to-mem enabled='no'/> <suspend-to-disk enabled='no'/> </pm>	The S3 and S4 ACPI sleep states are disabled for this VM.

<devices>
 <emulator>/usr/libexec/qemu-kvm</emulator>
 <disk type='file' device='disk'>
  <driver name='qemu' type='qcow2'/>
  <source file='/var/lib/libvirt/images/Testguest.qcow2'/>
  <target dev='vda' bus='virtio'/>
 </disk>
 <disk type='file' device='cdrom'>
  <driver name='qemu' type='raw'/>
  <target dev='sdb' bus='sata'/>
  <readonly/>
 </disk>
	The VM uses the **/usr/libexec/qemu-kvm** binary file for emulation and it has two disk devices attached.
	The first disk is a virtualized hard-drive based on the **/var/lib/libvirt/images/Testguest.qcow2** stored on the host, and its logical device name is set to **vda**.
	The second disk is a virtualized CD-ROM and its logical device name is set to **sdb**.

Domain XML Section	Description
<controller type='usb' index='0' model='qemu-xhci' ports='15'/> <controller type='sata' index='0'/> <controller type='pci' index='0' model='pcie-root'/> <controller type='pci' index='1' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='1' port='0x10'/> </controller> <controller type='pci' index='2' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='2' port='0x11'/> </controller> <controller type='pci' index='3' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='3' port='0x12'/> </controller> <controller type='pci' index='4' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='4' port='0x13'/> </controller> <controller type='pci' index='5' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='5' port='0x14'/> </controller> <controller type='pci' index='6' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='6' port='0x15'/> </controller> <controller type='pci' index='7' model='pcie-root-port'> <model name='pcie-root-port'/> <target chassis='7' port='0x16'/> </controller> <controller type='virtio-serial' index='0'/>	The VM uses a single controller for attaching USB devices, and a root controller for PCI-Express (PCIe) devices. In addition, a **virtio-serial** controller is available, which enables the VM to interact with the host in a variety of ways, such as the serial console. For more information about virtual devices, see Types of virtual devices.
<interface type='network'> <mac address='52:54:00:65:29:21'/> <source network='default'/> <model type='virtio'/> </interface>	A network interface is set up in the VM that uses the **default** virtual network and the **virtio** network device model. For information about configuring the network interface, see Optimizing virtual machine network performance.

Domain XML Section	Description

`<serial type='pty'>`
`<target type='isa-serial' port='0'>`
`<model name='isa-serial'/>`
`</target>`
`</serial>`
`<console type='pty'>`
`<target type='serial' port='0'/>`
`</console>`
`<channel type='unix'>`
`<target type='virtio' name='org.qemu.guest_agent.0'/>`
`<address type='virtio-serial' controller='0' bus='0' port='1'/>`
`</channel>`
	A **pty** serial console is set up on the VM, which enables rudimentary VM communication with the host. The console uses the **UNIX** channel on port 1. This is set up automatically and changing these settings is not recommended.
	For more information about interacting with VMs, see Interacting with virtual machines by using the web console.

`<input type='tablet' bus='usb'>`
`<address type='usb' bus='0' port='1'/>`
`</input>`
`<input type='mouse' bus='ps2'/>`
`<input type='keyboard' bus='ps2'/>`
	The VM uses a virtual **usb** port, which is set up to receive tablet input, and a virtual **ps2** port set up to receive mouse and keyboard input. This is set up automatically and changing these settings is not recommended.

`<graphics type='vnc' port='-1' autoport='yes' listen='127.0.0.1'>`
`<listen type='address' address='127.0.0.1'/>`
`</graphics>`
	The VM uses the **vnc** protocol for rendering its graphical output.

`<redirdev bus='usb' type='tcp'>`
`<source mode='connect' host='localhost' service='4000'/>`
`<protocol type='raw'/>`
`</redirdev>`
`<memballoon model='virtio'>`
`<address type='pci' domain='0x0000' bus='0x00' slot='0x07' function='0x0'/>`
`</memballoon>`
`</devices>`
`</domain>`
	The VM uses **tcp** re-director for attaching USB devices remotely, and memory ballooning is turned on. This is set up automatically and changing these settings is not recommended.

CHAPTER 10. SAVING AND RESTORING VIRTUAL MACHINES

To free up system resources, you can shut down a virtual machine (VM) running on that system. However, when you require the VM again, you must boot up the guest operating system (OS) and restart the applications, which may take a considerable amount of time. To reduce this downtime and enable the VM workload to start running sooner, you can use the save and restore feature to avoid the OS shutdown and boot sequence entirely.

This section provides information about saving VMs, as well as about restoring them to the same state without a full VM boot-up.

10.1. HOW SAVING AND RESTORING VIRTUAL MACHINES WORKS

Saving a virtual machine (VM) saves its memory and device state to the host's disk, and immediately stops the VM process. You can save a VM that is either in a running or paused state, and upon restoring, the VM will return to that state.

This process frees up RAM and CPU resources on the host system in exchange for disk space, which may improve the host system performance. When the VM is restored, because the guest OS does not need to be booted, the long boot-up period is avoided as well.

To save a VM, you can use the command line (CLI). For instructions, see Saving virtual machines by using the command line.

To restore a VM you can use the CLI or the web console GUI.

You can also save and restore the state of a VM by using snapshots. For more information, see Saving and restoring virtual machine state by using snapshots.

10.2. SAVING A VIRTUAL MACHINE BY USING THE COMMAND LINE

You can save a virtual machine (VM) and its current state to the host's disk. This is useful, for example, when you need to use the host's resources for some other purpose. The saved VM can then be quickly restored to its previous running state.

To save a VM by using the command line, follow the procedure below.

Prerequisites

- Ensure you have sufficient disk space to save the VM and its configuration. Note that the space occupied by the VM depends on the amount of RAM allocated to that VM.
- Ensure the VM is persistent.
- Optional: Back up important data from the VM if required.

Procedure

- Use the **virsh managedsave** utility.
  For example, the following command stops the *demo-guest1* VM and saves its configuration.

```
# virsh managedsave demo-guest1
Domain 'demo-guest1' saved by libvirt
```

The saved VM file is located by default in the **/var/lib/libvirt/qemu/save** directory as **demo-guest1.save**.

The next time the VM is started, it will automatically restore the saved state from the above file.

Verification

- List the VMs that have managed save enabled. In the following example, the VMs listed as *saved* have their managed save enabled.

  ```
  # virsh list --managed-save --all
  Id    Name                          State
  ----------------------------------------------------
  -     demo-guest1                   saved
  -     demo-guest2                   shut off
  ```

  To list the VMs that have a managed save image:

  ```
  # virsh list --with-managed-save --all
  Id    Name                          State
  ----------------------------------------------------
  -     demo-guest1                   shut off
  ```

  Note that to list the saved VMs that are in a shut off state, you must use the **--all** or **--inactive** options with the command.

Troubleshooting

- If the saved VM file becomes corrupted or unreadable, restoring the VM will initiate a standard VM boot instead.

Additional resources

- The **virsh managedsave --help** command
- Restoring a saved VM by using the command line
- Restoring a saved VM by using the web console

10.3. STARTING A VIRTUAL MACHINE BY USING THE COMMAND LINE

You can use the command line (CLI) to start a shut-down virtual machine (VM) or restore a saved VM. By using the CLI, you can start both local and remote VMs.

Prerequisites

- An inactive VM that is already defined.
- The name of the VM.
- For remote VMs:
  - The IP address of the host where the VM is located.
  - Root access privileges to the host.

Procedure

- For a local VM, use the **virsh start** utility.
  For example, the following command starts the *demo-guest1* VM.

  ```
  # virsh start demo-guest1
  Domain 'demo-guest1' started
  ```

- For a VM located on a remote host, use the **virsh start** utility along with the QEMU+SSH connection to the host.
  For example, the following command starts the *demo-guest1* VM on the 192.0.2.1 host.

  ```
  # virsh -c qemu+ssh://root@192.0.2.1/system start demo-guest1

  root@192.0.2.1's password:

  Domain 'demo-guest1' started
  ```

Additional resources

- The **virsh start --help** command
- Setting up easy access to remote virtualization hosts
- Starting virtual machines automatically when the host starts

10.4. STARTING VIRTUAL MACHINES BY USING THE WEB CONSOLE

If a virtual machine (VM) is in the *shut off* state, you can start it by using the RHEL 9 web console. You can also configure the VM to be started automatically when the host starts.

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 web console VM plug-in is installed on your system.
- An inactive VM that is already defined.
- The name of the VM.

Procedure

1. In the **Virtual Machines** interface, click the VM you want to start.
   A new page opens with detailed information about the selected VM and controls for shutting down and deleting the VM.
2. Click **Run**.
   The VM starts, and you can connect to its console or graphical output .

3. Optional: To configure the VM to start automatically when the host starts, toggle the **Autostart** checkbox in the **Overview** section.
   If you use network interfaces that are not managed by libvirt, you must also make additional changes to the systemd configuration. Otherwise, the affected VMs might fail to start, see starting virtual machines automatically when the host starts .

Additional resources

- Shutting down virtual machines in the web console
- Restarting virtual machines by using the web console

CHAPTER 11. CLONING VIRTUAL MACHINES

To quickly create a new virtual machine (VM) with a specific set of properties, you can *clone* an existing VM.

Cloning creates a new VM that uses its own disk image for storage, but most of the clone's configuration and stored data is identical to the source VM. This makes it possible to prepare multiple VMs optimized for a certain task without the need to optimize each VM individually.

11.1. HOW CLONING VIRTUAL MACHINES WORKS

Cloning a virtual machine (VM) copies the XML configuration of the source VM and its disk images, and makes adjustments to the configurations to ensure the uniqueness of the new VM. This includes changing the name of the VM and ensuring it uses the disk image clones. Nevertheless, the data stored on the clone's virtual disks is identical to the source VM.

This process is faster than creating a new VM and installing it with a guest operating system, and can be used to rapidly generate VMs with a specific configuration and content.

If you are planning to create multiple clones of a VM, first create a VM *template* that does not contain:

- Unique settings, such as persistent network MAC configuration, which can prevent the clones from working correctly.
- Sensitive data, such as SSH keys and password files.

For instructions, see Creating virtual machines templates.

Additional resources

- Cloning a virtual machine by using the command line
- Cloning a virtual machine by using the web console

11.2. CREATING VIRTUAL MACHINE TEMPLATES

To create multiple virtual machine (VM) clones that work correctly, you can remove information and configurations that are unique to a source VM, such as SSH keys or persistent network MAC configuration. This creates a VM *template*, which you can use to easily and safely create VM clones.

You can create VM templates by using the **virt-sysprep** utility or you can create them manually based on your requirements.

11.2.1. Creating a virtual machine template by using virt-sysprep

To create a cloning template from an existing virtual machine (VM), you can use the **virt-sysprep** utility. This removes certain configurations that might cause the clone to work incorrectly, such as specific network settings or system registration metadata. As a result, **virt-sysprep** makes creating clones of the VM more efficient, and ensures that the clones work more reliably.

Prerequisites

- The **guestfs-tools** package, which contains the **virt-sysprep** utility, is installed on your host:

```
# dnf install guestfs-tools
```

- The source VM intended as a template is shut down.
- You know where the disk image for the source VM is located, and you are the owner of the VM's disk image file.
  Note that disk images for VMs created in the system connection of libvirt are located in the **/var/lib/libvirt/images** directory and owned by the root user by default:

  ```
  # ls -la /var/lib/libvirt/images
  -rw-------.  1 root root  9665380352 Jul 23 14:50 a-really-important-vm.qcow2
  -rw-------.  1 root root  8591507456 Jul 26  2017 an-actual-vm-that-i-use.qcow2
  -rw-------.  1 root root  8591507456 Jul 26  2017 totally-not-a-fake-vm.qcow2
  -rw-------.  1 root root 10739318784 Sep 20 17:57 another-vm-example.qcow2
  ```

- Optional: Any important data on the source VM's disk has been backed up. If you want to preserve the source VM intact, clone it first and turn the clone into a template.

Procedure

1. Ensure you are logged in as the owner of the VM's disk image:

   ```
   # whoami
   root
   ```

2. Optional: Copy the disk image of the VM.

   ```
   # cp /var/lib/libvirt/images/a-really-important-vm.qcow2 /var/lib/libvirt/images/a-really-important-vm-original.qcow2
   ```

   This is used later to verify that the VM was successfully turned into a template.

3. Use the following command, and replace */var/lib/libvirt/images/a-really-important-vm.qcow2* with the path to the disk image of the source VM.

   ```
   # virt-sysprep -a /var/lib/libvirt/images/a-really-important-vm.qcow2
   [   0.0] Examining the guest ...
   [   7.3] Performing "abrt-data" ...
   [   7.3] Performing "backup-files" ...
   [   9.6] Performing "bash-history" ...
   [   9.6] Performing "blkid-tab" ...
   [...]
   ```

Verification

- To confirm that the process was successful, compare the modified disk image to the original one. The following example shows a successful creation of a template:

  ```
  # virt-diff -a /var/lib/libvirt/images/a-really-important-vm-orig.qcow2 -A /var/lib/libvirt/images/a-really-important-vm.qcow2
  - - 0644       1001 /etc/group-
  - - 0000        797 /etc/gshadow-
  = - 0444         33 /etc/machine-id
  ```

```
[...]
- - 0600       409 /home/username/.bash_history
- d 0700         6 /home/username/.ssh
- - 0600       868 /root/.bash_history
[...]
```

Additional resources

- The **OPERATIONS** section in the **virt-sysprep** man page on your system
- Cloning a virtual machine by using the command line

11.2.2. Creating a virtual machine template manually

To create a template from an existing virtual machine (VM), you can manually reset or unconfigure a guest VM to prepare it for cloning.

Prerequisites

- Ensure that you know the location of the disk image for the source VM and are the owner of the VM's disk image file.
  Note that disk images for VMs created in the system connection of libvirt are by default located in the **/var/lib/libvirt/images** directory and owned by the root user:

  ```
  # ls -la /var/lib/libvirt/images
  -rw-------.  1 root root  9665380352 Jul 23 14:50 a-really-important-vm.qcow2
  -rw-------.  1 root root  8591507456 Jul 26  2017 an-actual-vm-that-i-use.qcow2
  -rw-------.  1 root root  8591507456 Jul 26  2017 totally-not-a-fake-vm.qcow2
  -rw-------.  1 root root 10739318784 Sep 20 17:57 another-vm-example.qcow2
  ```

- Ensure that the VM is shut down.
- Optional: Any important data on the VM's disk has been backed up. If you want to preserve the source VM intact, clone it first and edit the clone to create a template.

Procedure

1. Configure the VM for cloning:
   a. Install any software needed on the clone.
   b. Configure any non-unique settings for the operating system.
   c. Configure any non-unique application settings.
2. Remove the network configuration:
   a. Remove any persistent udev rules by using the following command:

      ```
      # rm -f /etc/udev/rules.d/70-persistent-net.rules
      ```

NOTE

If udev rules are not removed, the name of the first NIC might be **eth1** instead of **eth0**.

b. Remove unique information from the **NMConnection** files in the **/etc/NetworkManager/system-connections/** directory.

   i. Remove MAC address, IP address, DNS, gateway, and any other **unique** information or non-desired settings.

```
*ID=ExampleNetwork
BOOTPROTO="dhcp"
HWADDR="AA:BB:CC:DD:EE:FF"                  <- REMOVE
NM_CONTROLLED="yes"
ONBOOT="yes"
TYPE="Ethernet"
UUID="954bd22c-f96c-4b59-9445-b39dd86ac8ab" <- REMOVE
```

   ii. Remove similar **unique** information and non-desired settings from the **/etc/hosts** and **/etc/resolv.conf** files.

3. Remove registration details:

- For VMs registered on the Red Hat Network (RHN):

```
# rm /etc/sysconfig/rhn/systemid
```

- For VMs registered with Red Hat Subscription Manager (RHSM):

  - If you do not plan to use the original VM:

```
# subscription-manager unsubscribe --all # subscription-manager unregister #
subscription-manager clean
```

  - If you plan to use the original VM:

```
# subscription-manager clean
```

NOTE

The original RHSM profile remains in the Portal along with your ID code. Use the following command to reactivate your RHSM registration on the VM after it is cloned:

```
# subscription-manager register --consumerid=71rd64fx-6216-4409-
bf3a-e4b7c7bd8ac9
```

4. Remove other unique details:

a. Remove SSH public and private key pairs:

```
# rm -rf /etc/ssh/ssh_host_example
```

b. Remove the configuration of LVM devices:

```
# rm /etc/lvm/devices/system.devices
```

c. Remove any other application-specific identifiers or configurations that might cause conflicts if running on multiple machines.

5. Remove the **gnome-initial-setup-done** file to configure the VM to run the configuration wizard on the next boot:

```
# rm ~/.config/gnome-initial-setup-done
```

NOTE

The wizard that runs on the next boot depends on the configurations that have been removed from the VM. In addition, on the first boot of the clone, it is recommended that you change the hostname.

11.3. CLONING A VIRTUAL MACHINE BY USING THE COMMAND LINE

For testing, to create a new virtual machine (VM) with a specific set of properties, you can clone an existing VM by using CLI.

Prerequisites

- The source VM is shut down.
- Ensure that there is sufficient disk space to store the cloned disk images.
- Optional: When creating multiple VM clones, remove unique data and settings from the source VM to ensure the cloned VMs work properly. For instructions, see Creating virtual machine templates.

Procedure

- Use the **virt-clone** utility with options that are appropriate for your environment and use case.
  Sample use cases
  - The following command clones a local VM named **example-VM-1** and creates the **example-VM-1-clone** VM. It also creates and allocates the **example-VM-1-clone.qcow2** disk image in the same location as the disk image of the original VM, and with the same data:

```
# virt-clone --original example-VM-1 --auto-clone
Allocating 'example-VM-1-clone.qcow2'                | 50.0 GB  00:05:37

Clone 'example-VM-1-clone' created successfully.
```

  - The following command clones a VM named **example-VM-2**, and creates a local VM named **example-VM-3**, which uses only two out of multiple disks of **example-VM-2**:

```
# virt-clone --original example-VM-2 --name example-VM-3 --file
/var/lib/libvirt/images/disk-1-example-VM-2.qcow2 --file /var/lib/libvirt/images/disk-2-
example-VM-2.qcow2
```

```
Allocating 'disk-1-example-VM-2-clone.qcow2'                    | 78.0 GB  00:05:37
Allocating 'disk-2-example-VM-2-clone.qcow2'                    | 80.0 GB  00:05:37

Clone 'example-VM-3' created successfully.
```

- To clone your VM to a different host, migrate the VM without undefining it on the local host. For example, the following commands clone the previously created **example-VM-3** VM to the **192.0.2.1** remote system, including its local disks. Note that you require root privileges to run these commands for **192.0.2.1**:

```
# virsh migrate --offline --persistent example-VM-3 qemu+ssh://root@192.0.2.1/system
root@192.0.2.1's password:

# scp /var/lib/libvirt/images/<disk-1-example-VM-2-clone>.qcow2
root@192.0.2.1/<user@remote_host.com>://var/lib/libvirt/images/

# scp /var/lib/libvirt/images/<disk-2-example-VM-2-clone>.qcow2
root@192.0.2.1/<user@remote_host.com>://var/lib/libvirt/images/
```

Verification

1. To verify the VM has been successfully cloned and is working correctly:

   a. Confirm the clone has been added to the list of VMs on your host:

```
# virsh list --all
Id   Name                  State
---------------------------------------
-    example-VM-1          shut off
-    example-VM-1-clone    shut off
```

   b. Start the clone and observe if it boots up:

```
# virsh start example-VM-1-clone
Domain 'example-VM-1-clone' started
```

Additional resources

- **virt-clone (1)** man page on your system
- Migrating virtual machines

11.4. CLONING A VIRTUAL MACHINE BY USING THE WEB CONSOLE

To create new virtual machines (VMs) with a specific set of properties, you can clone a VM that you had previously configured by using the web console.

> **NOTE**
>
> Cloning a VM also clones the disks associated with that VM.

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 web console VM plug-in is installed on your system.

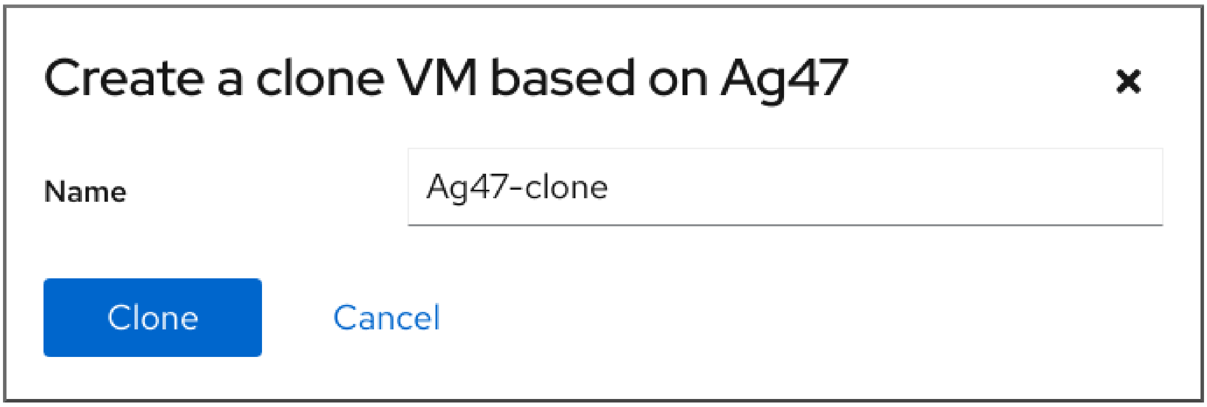
- Ensure that the VM you want to clone is shut down.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. In the Virtual Machines interface of the web console, click the Menu button ⋮ of the VM that you want to clone.
   A drop down menu appears with controls for various VM operations.

3. Click **Clone**.
   The Create a clone VM dialog appears.



Create a clone VM based on Ag47

Name: Ag47-clone

4. Optional: Enter a new name for the VM clone.

5. Click **Clone**.
   A new VM is created based on the source VM.

Verification

- Confirm whether the cloned VM appears in the list of VMs available on your host.

CHAPTER 12. MIGRATING VIRTUAL MACHINES

If the current host of a virtual machine (VM) becomes unsuitable or cannot be used anymore, or if you want to redistribute the hosting workload, you can migrate the VM to another KVM host.

12.1. HOW MIGRATING VIRTUAL MACHINES WORKS

You can migrate a running virtual machine (VM) without interrupting the workload, with only a small downtime, by using a *live* migration. By default, the migrated VM is transient on the destination host, and remains defined also on the source host. The essential part of a *live* migration is transferring the state of the VM's memory and of any attached virtualized devices to a destination host. For the VM to remain functional on the destination host, the VM's disk images must remain available to it.

To migrate a shut-off VM, you must use an *offline* migration, which copies the VM's configuration to the destination host. For details, see the following table.

Table 12.1. VM migration types

Migration type	Description	Use case	Storage requirements
Live migration	The VM continues to run on the source host machine while KVM is transferring the VM's memory pages to the destination host. When the migration is nearly complete, KVM very briefly suspends the VM, and resumes it on the destination host.	Useful for VMs that require constant uptime. However, for VMs that modify memory pages faster than KVM can transfer them, such as VMs under heavy I/O load, the live migration might fail. (1)	The VM's disk images must be accessible both to the source host and the destination host during the migration. (2)
Offline migration	Moves the VM's configuration to the destination host	Recommended for shut-off VMs and in situations when shutting down the VM does not disrupt your workloads.	The VM's disk images do not have to be accessible to the source or destination host during migration, and can be copied or moved manually to the destination host instead.

(1) For possible solutions, see: Additional **virsh migrate** options for live migrations

(2) To achieve this, use one of the following:

- Storage located on a shared network
- The **--copy-storage-all** parameter for the **virsh migrate** command, which copies disk image contents from the source to the destination over the network.
- Storage area network (SAN) logical units (LUNs).
- Ceph storage clusters

NOTE

For easier management of large-scale migrations, explore other Red Hat products, such as:

- OpenShift Virtualization
- Red Hat OpenStack Platform

Additional resources

- Benefits of migrating virtual machines
- Sharing virtual machine disk images with other hosts

12.2. BENEFITS OF MIGRATING VIRTUAL MACHINES

Migrating virtual machines (VMs) can be useful for:

Load balancing

VMs can be moved to host machines with lower usage if their host becomes overloaded, or if another host is under-utilized.

Hardware independence

When you need to upgrade, add, or remove hardware devices on the host machine, you can safely relocate VMs to other hosts. This means that VMs do not experience any downtime for hardware improvements.

Energy saving

VMs can be redistributed to other hosts, and the unloaded host systems can thus be powered off to save energy and cut costs during low usage periods.

Geographic migration

VMs can be moved to another physical location for lower latency or when required for other reasons.

12.3. LIMITATIONS FOR MIGRATING VIRTUAL MACHINES

Before migrating virtual machines (VMs) in RHEL 9, ensure you are aware of the migration's limitations.

- VMs that use certain features and configurations will not work correctly if migrated, or the migration will fail. Such features include:
  - Device passthrough
  - SR-IOV device assignment (With the exception of migrating a VM with an attached virtual function of a Mellanox networking device, which works correctly.)
  - Mediated devices, such as vGPUs (With the exception of migrating a VM with an attached NVIDIA vGPU, which works correctly.)
- A migration between hosts that use Non-Uniform Memory Access (NUMA) pinning works only if the hosts have similar topology. However, the performance on running workloads might be negatively affected by the migration.
- Both the source and destination hosts use specific RHEL versions that are supported for VM migration, see Supported hosts for virtual machine migration

- The physical CPUs, both on the source VM and the destination VM, must be identical, otherwise the migration might fail. Any differences between the VMs in the following CPU related areas can cause problems with the migration:
  - CPU model
    - Migrating between an Intel 64 host and an AMD64 host is unsupported, even though they share the x86-64 instruction set.
    - For steps to ensure that a VM will work correctly after migrating to a host with a different CPU model, see Verifying host CPU compatibility for virtual machine migration.
  - Physical machine firmware versions and settings

12.4. MIGRATING A VIRTUAL MACHINE BY USING THE COMMAND LINE

If the current host of a virtual machine (VM) becomes unsuitable or cannot be used anymore, or if you want to redistribute the hosting workload, you can migrate the VM to another KVM host. You can perform a *live migration* or an *offline migration*. For differences between the two scenarios, see How migrating virtual machines works.

Prerequisites

- **Hypervisor:** The source host and the destination host both use the KVM hypervisor.
- **Network connection:** The source host and the destination host are able to reach each other over the network. Use the **ping** utility to verify this.
- **Open ports:** Ensure the following ports are open on the destination host.
  - Port 22 is needed for connecting to the destination host by using SSH.
  - Port 16514 is needed for connecting to the destination host by using TLS.
  - Port 16509 is needed for connecting to the destination host by using TCP.
  - Ports 49152-49215 are needed by QEMU for transferring the memory and disk migration data.
- **Hosts:** For the migration to be supportable by Red Hat, the source host and destination host must be using specific operating systems and machine types. To ensure this is the case, see Supported hosts for virtual machine migration .
- **CPU:** The VM must be compatible with the CPU features of the destination host. To ensure this is the case, see Verifying host CPU compatibility for virtual machine migration .
- **Storage:** The disk images of VMs that will be migrated are accessible to both the source host and the destination host. This is optional for offline migration, but required for migrating a running VM. To ensure storage accessibility for both hosts, one of the following must apply:
  - You are using storage area network (SAN) logical units (LUNs).
  - You are using a Ceph storage clusters .

  - You have created a disk image with the same format and size as the source VM disk and you will use the **--copy-storage-all** parameter when migrating the VM.
  - The disk image is located on a separate networked location. For instructions to set up such shared VM storage, see Sharing virtual machine disk images with other hosts .

- **Network bandwidth:** When migrating a running VM, your network bandwidth must be higher than the rate in which the VM generates dirty memory pages.
  To obtain the dirty page rate of your VM before you start the live migration, do the following:
  - Monitor the rate of dirty page generation of the VM for a short period of time.

    ```
    # virsh domdirtyrate-calc <example_VM> 30
    ```

  - After the monitoring finishes, obtain its results:

    ```
    # virsh domstats <example_VM> --dirtyrate
    Domain: 'example-VM'
      dirtyrate.calc_status=2
      dirtyrate.calc_start_time=200942
      dirtyrate.calc_period=30
      dirtyrate.megabytes_per_second=2
    ```

    In this example, the VM is generating 2 MB of dirty memory pages per second. Attempting to live-migrate such a VM on a network with a bandwidth of 2 MB/s or less will cause the live migration not to progress if you do not pause the VM or lower its workload.

    To ensure that the live migration finishes successfully, Red Hat recommends that your network bandwidth is significantly greater than the VM's dirty page generation rate.

    NOTE

    The value of the **calc_period** option might differ based on the workload and dirty page rate. You can experiment with several **calc_period** values to determine the most suitable period that aligns with the dirty page rate in your environment.

- **Bridge tap network specifics:** When migrating an existing VM in a public bridge tap network, the source and destination hosts must be located on the same network. Otherwise, the VM network will not work after migration.

- **Connection protocol:** When performing a VM migration, the **virsh** client on the source host can use one of several protocols to connect to the libvirt daemon on the destination host. Examples in the following procedure use an SSH connection, but you can choose a different one.
  - If you want libvirt to use an SSH connection, ensure that the **virtqemud** socket is enabled and running on the destination host.

    ```
    # systemctl enable --now virtqemud.socket
    ```

  - If you want libvirt to use a TLS connection, ensure that the **virtproxyd-tls** socket is enabled and running on the destination host.

    ```
    # systemctl enable --now virtproxyd-tls.socket
    ```

   - If you want libvirt to use a TCP connection, ensure that the **virtproxyd-tcp** socket is enabled and running on the destination host.

     ```
     # systemctl enable --now virtproxyd-tcp.socket
     ```

Procedure

To migrate a VM from one host to another, use the **virsh migrate** command.

Offline migration

- The following command migrates a shut-off **example-VM** VM from your local host to the system connection of the **example-destination** host by using an SSH tunnel.

  ```
  # virsh migrate --offline --persistent <example_VM> qemu+ssh://example-destination/system
  ```

Live migration

1. The following command migrates the **example-VM** VM from your local host to the system connection of the **example-destination** host by using an SSH tunnel. The VM keeps running during the migration.

   ```
   # virsh migrate --live --persistent <example_VM> qemu+ssh://example-destination/system
   ```

2. Wait for the migration to complete. The process might take some time depending on network bandwidth, system load, and the size of the VM. If the **--verbose** option is not used for **virsh migrate**, the CLI does not display any progress indicators except errors.
   When the migration is in progress, you can use the **virsh domjobinfo** utility to display the migration statistics.

Multi-FD live migration

- You can use multiple parallel connections to the destination host during the live migration. This is also known as multiple file descriptors (multi-FD) migration. With multi-FD migration, you can speed up the migration by utilizing all of the available network bandwidth for the migration process.

  ```
  # virsh migrate --live --persistent --parallel --parallel-connections 4 <example_VM>
  qemu+ssh://<example-destination>/system
  ```

  This example uses 4 multi-FD channels to migrate the *<example_VM>* VM. It is recommended to use one channel for each 10 Gbps of available network bandwidth. The default value is 2 channels.

Live migration with an increased downtime limit

- To improve the reliability of a live migration, you can set the **maxdowntime** parameter, which specifies the maximum amount of time, in milliseconds, the VM can be paused during live migration. Setting a larger downtime can help to ensure the migration completes successfully.

  ```
  # virsh migrate-setmaxdowntime <example_VM> <time_interval_in_milliseconds>
  ```

Live migration with passwordless SSH authentication

- To avoid the need to input the SSH password for the remote host during the migration, you can specify a private key file for the migration to use instead. This can be useful for example in automated migration scripts, or for peer-to-peer migration.

  ```
  # virsh migrate --live --persistent <example_VM> qemu+ssh://<example-destination>/system?keyfile=<path_to_key>
  ```

Post-copy migration

- If your VM has a large memory footprint, you can perform a *post-copy* migration, which transfers the source VM's CPU state first and immediately starts the migrated VM on the destination host. The source VM's memory pages are transferred after the migrated VM is already running on the destination host. Because of this, a *post-copy* migration can result in a smaller downtime of the migrated VM.
  However, the running VM on the destination host might try to access memory pages that have not yet been transferred, which causes a *page fault*. If too many *page faults* occur during the migration, the performance of the migrated VM can be severely degraded.

  Given the potential complications of a *post-copy* migration, it is recommended to use the following command that starts a standard live migration and switches to a *post-copy* migration if the live migration cannot be finished in a specified amount of time.

  ```
  # virsh migrate --live --persistent --postcopy --timeout <time_interval_in_seconds> --timeout-postcopy <example_VM> qemu+ssh://<example-destination>/system
  ```

Auto-converged live migration

- If your VM is under a heavy memory workload, you can use the **--auto-converge** option. This option automatically slows down the execution speed of the VM's CPU. As a consequence, this CPU throttling can help to slow down memory writes, which means the live migration might succeed even in VMs with a heavy memory workload.
  However, the CPU throttling does not help to resolve workloads where memory writes are not directly related to CPU execution speed, and it can negatively impact the performance of the VM during a live migration.

  ```
  # virsh migrate --live --persistent --auto-converge <example_VM> qemu+ssh://<example-destination>/system
  ```

Verification

- For *offline* migration:
  - On the destination host, list the available VMs to verify that the VM was migrated successfully.

    ```
    # virsh list --all
    Id     Name            State
    ----------------------------------
    10    example-VM-1      shut off
    ```

- For *live* migration:
  - On the destination host, list the available VMs to verify the state of the destination VM:

```
# virsh list --all
Id      Name             State
----------------------------------
10    example-VM-1      running
```

If the state of the VM is listed as **running**, it means that the migration is finished. However, if the live migration is still in progress, the state of the destination VM will be listed as **paused**.

- For *post-copy* migration:

a. On the source host, list the available VMs to verify the state of the source VM.

```
# virsh list --all
Id      Name             State
----------------------------------
10    example-VM-1      shut off
```

b. On the destination host, list the available VMs to verify the state of the destination VM.

```
# virsh list --all
Id      Name             State
----------------------------------
10    example-VM-1      running
```

If the state of the source VM is listed as **shut off** and the state of the destination VM is listed as **running**, it means that the migration is finished.

Additional resources

- **virsh migrate --help** command
- **virsh (1)** man page on your system

12.5. LIVE MIGRATING A VIRTUAL MACHINE BY USING THE WEB CONSOLE

If you want to migrate a virtual machine (VM) that is performing tasks which require it to be constantly running, you can migrate that VM to another KVM host without shutting it down. This is also known as live migration. The following instructions explain how to do so by using 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 web console VM plugin is installed on your system .
- **Hypervisor:** The source host and the destination host both use the KVM hypervisor.

- **Hosts:** The source and destination hosts are running.
- **Open ports:** Ensure the following ports are open on the destination host.
  - Port 22 is needed for connecting to the destination host by using SSH.
  - Port 16514 is needed for connecting to the destination host by using TLS.
  - Port 16509 is needed for connecting to the destination host by using TCP.
  - Ports 49152-49215 are needed by QEMU for transfering the memory and disk migration data.
- **CPU:** The VM must be compatible with the CPU features of the destination host. To ensure this is the case, see Verifying host CPU compatibility for virtual machine migration .
- **Storage:** The disk images of VMs that will be migrated are accessible to both the source host and the destination host. This is optional for offline migration, but required for migrating a running VM. To ensure storage accessibility for both hosts, one of the following must apply:
  - You are using storage area network (SAN) logical units (LUNs).
  - You are using a Ceph storage clusters .
  - You have created a disk image with the same format and size as the source VM disk and you will use the **--copy-storage-all** parameter when migrating the VM.
  - The disk image is located on a separate networked location. For instructions to set up such shared VM storage, see Sharing virtual machine disk images with other hosts .
- **Network bandwidth:** When migrating a running VM, your network bandwidth must be higher than the rate in which the VM generates dirty memory pages.
  To obtain the dirty page rate of your VM before you start the live migration, do the following on the command line:

  a. Monitor the rate of dirty page generation of the VM for a short period of time.

  ```
  # virsh domdirtyrate-calc vm-name 30
  ```

  b. After the monitoring finishes, obtain its results:

  ```
  # virsh domstats vm-name --dirtyrate
  Domain: 'vm-name'
    dirtyrate.calc_status=2
    dirtyrate.calc_start_time=200942
    dirtyrate.calc_period=30
    dirtyrate.megabytes_per_second=2
  ```

  In this example, the VM is generating 2 MB of dirty memory pages per second. Attempting to live-migrate such a VM on a network with a bandwidth of 2 MB/s or less will cause the live migration not to progress if you do not pause the VM or lower its workload.

  To ensure that the live migration finishes successfully, Red Hat recommends that your network bandwidth is significantly greater than the VM’s dirty page generation rate.

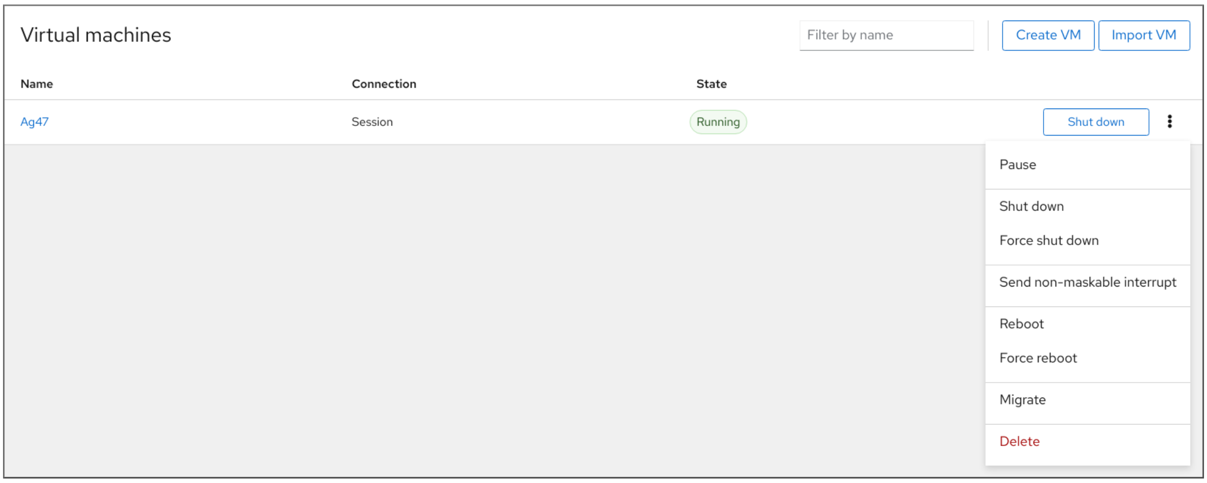
NOTE

The value of the **calc_period** option might differ based on the workload and dirty page rate. You can experiment with several **calc_period** values to determine the most suitable period that aligns with the dirty page rate in your environment.

- **Bridge tap network specifics:**When migrating an existing VM in a public bridge tap network, the source and destination hosts must be located on the same network. Otherwise, the VM network will not work after migration.

Procedure

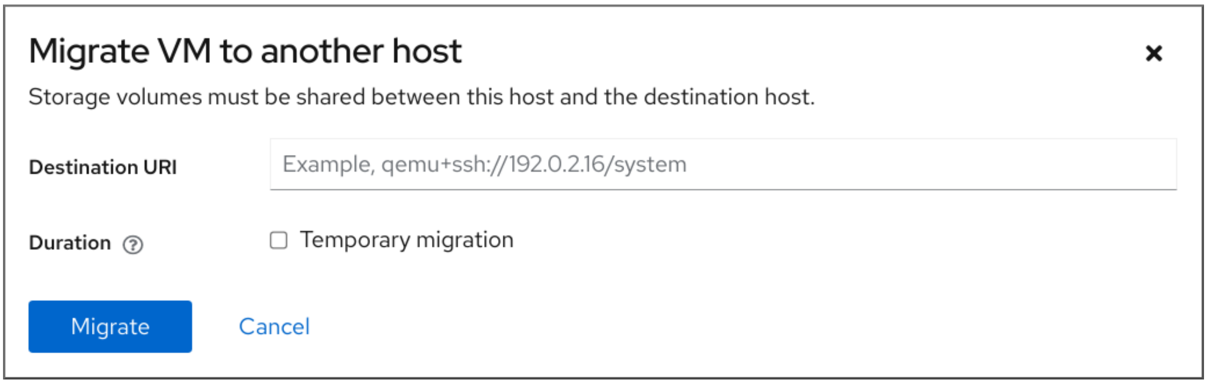
1. In the Virtual Machines interface of the web console, click the Menu button ⋮ of the VM that you want to migrate.
   A drop down menu appears with controls for various VM operations.



Virtual machines

Name	Connection	State
Ag47	Session	Running

2. Click **Migrate**
   The Migrate VM to another host dialog appears.



Migrate VM to another host

Storage volumes must be shared between this host and the destination host.

3. Enter the URI of the destination host.

4. Configure the duration of the migration:
   - **Permanent** - Do not check the box if you want to migrate the VM permanently. Permanent migration completely removes the VM configuration from the source host.
   - **Temporary** - Temporary migration migrates a copy of the VM to the destination host. This copy is deleted from the destination host when the VM is shut down. The original VM remains on the source host.

5. Click **Migrate**
   Your VM is migrated to the destination host.

Verification

To verify whether the VM has been successfully migrated and is working correctly:

- Confirm whether the VM appears in the list of VMs available on the destination host.

- Start the migrated VM and observe if it boots up.

12.6. LIVE MIGRATING A VIRTUAL MACHINE WITH AN ATTACHED MELLANOX VIRTUAL FUNCTION

You can live migrate a virtual machine (VM) with an attached virtual function (VF) of a supported Mellanox networking device.

Red Hat implements the general functionality of VM live migration with an attached VF of a Mellanox networking device. However, the functionality depends on specific Mellanox device models and firmware versions.

Currently, the VF migration is supported only with a Mellanox CX-7 networking device.

The VF on the Mellanox CX-7 networking device uses a new **mlx5_vfio_pci** driver, which adds functionality that is necessary for the live migration, and **libvirt** binds the new driver to the VF automatically.

Red Hat directly supports Mellanox VF live migration only with the included **mlx5_vfio_pci** driver.

Limitations

Some virtualization features cannot be used when live migrating a VM with an attached virtual function:

- Calculating dirty memory page rate generation of the VM.
  Currently, when migrating a VM with an attached Mellanox VF, live migration data and statistics provided by **virsh domjobinfo** and **virsh domdirtyrate-calc** commands are inaccurate, because the calculations only count guest RAM without including the impact of the attached VF.

- Using a post-copy live migration.

- Using a virtual I/O Memory Management Unit (vIOMMU) device in the VM.

Additional limitations that are specific to the Mellanox CX-7 networking device:

- A CX-7 device with the same Parameter-Set Identification (PSID) and the same firmware version must be used on both the source and the destination hosts.
  You can check the PSID of your device with the following command:

  ```
  # mstflint -d <device_pci_address> query | grep -i PSID

  PSID: MT_1090111019
  ```

- On one CX-7 physical function, you can use at maximum 4 VFs for live migration at the same time. For example, you can migrate one VM with 4 attached VFs, or 4 VMs with one VF attached to each VM.

Prerequisites

- You have a Mellanox CX-7 networking device with a firmware version that is equal to or greater than *28.36.1010*.
  Refer to Mellanox documentation for details about supported firmware versions and ensure you are using an up-to-date version of the firmware.

- The host uses the Intel 64, AMD64, or ARM 64 CPU architecture.

- The Mellanox firmware version on the source host must be the same as on the destination host.

- The **mstflint** package is installed on both the source and destination host:

  ```
  # dnf install mstflint
  ```

- The Mellanox CX-7 networking device has **VF_MIGRATION_MODE** set to **MIGRATION_ENABLED**:

  ```
  # mstconfig -d <device_pci_address> query | grep -i VF_migration

  VF_MIGRATION_MODE                    MIGRATION_ENABLED(2)
  ```

  - You can set **VF_MIGRATION_MODE** to **MIGRATION_ENABLED** by using the following command:

    ```
    # mstconfig -d <device_pci_address> set VF_MIGRATION_MODE=2
    ```

- The **openvswitch** package is installed on both the source and destination host:

  ```
  # dnf install openvswitch
  ```

- All of the general SR-IOV devices prerequisites. For details, see Attaching SR-IOV networking devices to virtual machines

- All of the general VM migration prerequisites. For details, see Migrating a virtual machine by using the command line

Procedure

1. On the source host, set the Mellanox networking device to the **switchdev** mode.

   ```
   # devlink dev eswitch set pci/<device_pci_address> mode switchdev
   ```

2. On the source host, create a virtual function on the Mellanox device.

   ```
   # echo 1 > /sys/bus/pci/devices/0000\:e1\:00.0/sriov_numvfs
   ```

   The /**0000\:e1\:00.0**/ part of the file path is based on the PCI address of the device. In the example it is: **0000:e1:00.0**

3. On the source host, unbind the VF from its driver.

   ```
   # virsh nodedev-detach <vf_pci_address> --driver pci-stub
   ```

You can view the PCI address of the VF by using the following command:

```
# lshw -c network -businfo

Bus info          Device        Class        Description
=========================================================================================
==
pci@0000:e1:00.0    enp225s0np0    network       MT2910 Family [ConnectX-7]
pci@0000:e1:00.1    enp225s0v0     network       ConnectX Family mlx5Gen Virtual Function
```

4. On the source host, enable the migration function of the VF.

   ```
   # devlink port function set pci/0000:e1:00.0/1 migratable enable
   ```

   In this example, **pci/0000:e1:00.0/1** refers to the first VF on the Mellanox device with the given PCI address.

5. On the source host, configure Open vSwitch (OVS) for the migration of the VF. If the Mellanox device is in **switchdev** mode, it cannot transfer data over the network.

   a. Ensure the **openvswitch** service is running.

      ```
      # systemctl start openvswitch
      ```

   b. Enable hardware offloading to improve networking performance.

      ```
      # ovs-vsctl set Open_vSwitch . other_config:hw-offload=true
      ```

   c. Increase the maximum idle time to ensure network connections remain open during the migration.

      ```
      # ovs-vsctl set Open_vSwitch . other_config:max-idle=300000
      ```

   d. Create a new bridge in the OVS instance.

      ```
      # ovs-vsctl add-br <bridge_name>
      ```

   e. Restart the **openvswitch** service.

      ```
      # systemctl restart openvswitch
      ```

   f. Add the physical Mellanox device to the OVS bridge.

      ```
      # ovs-vsctl add-port <bridge_name> enp225s0np0
      ```

      In this example, ***<bridge_name>*** is the name of the bridge you created in a previous step, and **enp225s0np0** is the network interface name of the Mellanox device.

   g. Add the VF of the Mellanox device to the OVS bridge.

      ```
      # ovs-vsctl add-port <bridge_name> enp225s0npf0vf0
      ```

In this example, ***<bridge_name>*** is the name of the bridge you created in step *d* and **enp225s0npf0vf0** is the network interface name of the VF.

6. Repeat steps 1-5 on the **destination host**.

7. On the source host, open a new file, such as **mlx_vf.xml**, and add the following XML configuration of the VF:

```
<interface type='hostdev' managed='yes'>
    <mac address='52:54:00:56:8c:f7'/>
    <source>
      <address type='pci' domain='0x0000' bus='0xe1' slot='0x00' function='0x1'/>
    </source>
</interface>
```

   This example configures a pass-through of the VF as a network interface for the VM. Ensure the MAC address is unique, and use the PCI address of the VF on the source host.

8. On the source host, attach the VF XML file to the VM.

```
# virsh attach-device <vm_name> mlx_vf.xml --live --config
```

   In this example, **mlx_vf.xml** is the name of the XML file with the VF configuration. Use the **--live** option to attach the device to a running VM.

9. On the source host, start the live migration of the running VM with the attached VF.

```
# virsh migrate --live --domain <vm_name> --desturi
qemu+ssh://<destination_host_ip_address>/system
```

   For more details about performing a live migration, see Migrating a virtual machine by using the command line

Verification

1. In the migrated VM, view the network interface name of the Mellanox VF.

```
# ifconfig

eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.10  netmask 255.255.255.0  broadcast 192.168.1.255
        inet6 fe80::a00:27ff:fe4e:66a1  prefixlen 64  scopeid 0x20<link>
        ether 08:00:27:4e:66:a1  txqueuelen 1000  (Ethernet)
        RX packets 100000  bytes 6543210 (6.5 MB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 100000  bytes 6543210 (6.5 MB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

enp4s0f0v0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.3.10  netmask 255.255.255.0  broadcast 192.168.3.255
        inet6 fe80::a00:27ff:fe4e:66c3  prefixlen 64  scopeid 0x20<link>
        ether 08:00:27:4e:66:c3  txqueuelen 1000  (Ethernet)
        RX packets 200000  bytes 12345678 (12.3 MB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 200000  bytes 12345678 (12.3 MB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

2. In the migrated VM, check that the Mellanox VF works, for example:

```
# ping -I <VF_interface_name> 8.8.8.8

PING 8.8.8.8 (8.8.8.8) from 192.168.3.10 <VF_interface_name>: 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_seq=1 ttl=57 time=27.4 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=57 time=26.9 ms

--- 8.8.8.8 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1002ms
rtt min/avg/max/mdev = 26.944/27.046/27.148/0.102 ms
```

Additional resources

- Mellanox networking documentation
- Attaching SR-IOV networking devices to virtual machines
- Migrating a virtual machine by using the command line

12.7. LIVE MIGRATING A VIRTUAL MACHINE WITH AN ATTACHED NVIDIA VGPU

If you use virtual GPUs (vGPUs) in your virtualization workloads, you can live migrate a running virtual machine (VM) with an attached vGPU to another KVM host. Currently, this is only possible with NVIDIA GPUs.

Prerequisites

- You have an NVIDIA GPU with an NVIDIA Virtual GPU Software Driver version that supports this functionality. Refer to the relevant NVIDIA vGPU documentation for more details.
- You have a correctly configured NVIDIA vGPU assigned to a VM. For instructions, see: Setting up NVIDIA vGPU devices

  NOTE

  It is also possible to live migrate a VM with multiple vGPU devices attached.

- The host uses RHEL 9.4 or later as the operating system.
- The host uses x86_64 CPU architecture.
- All of the vGPU migration prerequisites that are documented by NVIDIA. Refer to the relevant NVIDIA vGPU documentation for more details.
- All of the general VM migration prerequisites. For details, see Migrating a virtual machine by using the command line

Limitations

- Certain NVIDIA GPU features can disable the migration. For more information, see the specific NVIDIA documentation for your graphics card.
- Some GPU workloads are not compatible with the downtime that happens during a migration. As a consequence, the GPU workloads might stop or crash. It is recommended to test if your workloads are compatible with the downtime before attempting a vGPU live migration.
- Currently, some general virtualization features cannot be used when live migrating a VM with an attached vGPU:
  - Calculating dirty memory page rate generation of the VM.
    Currently, live migration data and statistics provided by **virsh domjobinfo** and **virsh domdirtyrate-calc** commands are inaccurate when migrating a VM with an attached vGPU, because the calculations only count guest RAM without including vRAM from the vGPU.
  - Using a post-copy live migration.
  - Using a virtual I/O Memory Management Unit (vIOMMU) device in the VM.

Procedure

- For instructions on how to proceed with the live migration, see: Migrating a virtual machine by using the command line

No additional parameters for the migration command are required for the attached vGPU device.

Additional resources

- General NVIDIA vGPU documentation
- General NVIDIA AI Enterprise documentation

12.8. SHARING VIRTUAL MACHINE DISK IMAGES WITH OTHER HOSTS

To perform a live migration of a virtual machine (VM) between supported KVM hosts, you must also migrate the storage of the running VM in a way that makes it possible for the VM to read from and write to the storage during the migration process.

One of the methods to do this is using shared VM storage. The following procedure provides instructions for sharing a locally stored VM image with the source host and the destination host by using the NFS protocol.

Prerequisites

- The VM intended for migration is shut down.
- Optional: A host system is available for hosting the storage that is not the source or destination host, but both the source and the destination host can reach it through the network. This is the optimal solution for shared storage and is recommended by Red Hat.
- Make sure that NFS file locking is not used as it is not supported in KVM.
- The NFS protocol is installed and enabled on the source and destination hosts. See Deploying an NFS server.

- The **virt_use_nfs** SELinux boolean is set to **on**.

  ```
  # setsebool virt_use_nfs 1
  ```

Procedure

1. Connect to the host that will provide shared storage. In this example, it is the **example-shared-storage** host:

   ```
   # ssh root@example-shared-storage
   root@example-shared-storage's password:
   Last login: Mon Sep 24 12:05:36 2019
   root~#
   ```

2. Create a directory on the **example-shared-storage** host that will hold the disk image and that will be shared with the migration hosts:

   ```
   # mkdir /var/lib/libvirt/shared-images
   ```

3. Copy the disk image of the VM from the source host to the newly created directory. The following example copies the disk image **example-disk-1** of the VM to the **/var/lib/libvirt/shared-images/** directory of the **example-shared-storage** host:

   ```
   # scp /var/lib/libvirt/images/example-disk-1.qcow2 root@example-shared-storage:/var/lib/libvirt/shared-images/example-disk-1.qcow2
   ```

4. On the host that you want to use for sharing the storage, add the sharing directory to the **/etc/exports** file. The following example shares the **/var/lib/libvirt/shared-images** directory with the **example-source-machine** and **example-destination-machine** hosts:

   ```
   # /var/lib/libvirt/shared-images example-source-machine(rw,no_root_squash) example-destination-machine(rw,no\_root_squash)
   ```

5. Run the **exportfs -a** command for the changes in the **/etc/exports** file to take effect.

   ```
   # exportfs -a
   ```

6. On both the source and destination host, mount the shared directory in the **/var/lib/libvirt/images** directory:

   ```
   # mount example-shared-storage:/var/lib/libvirt/shared-images /var/lib/libvirt/images
   ```

Verification

- Start the VM on the source host and observe if it boots successfully.

Additional resources

- Deploying an NFS server

12.9. VERIFYING HOST CPU COMPATIBILITY FOR VIRTUAL MACHINE MIGRATION

For migrated virtual machines (VMs) to work correctly on the destination host, the CPUs on the source and the destination hosts must be compatible. To ensure that this is the case, calculate a common CPU baseline before you begin the migration.

> **NOTE**
>
> The instructions in this section use an example migration scenario with the following host CPUs:
>
> - Source host: Intel Core i7-8650U
> - Destination hosts: Intel Xeon CPU E5-2620 v2
>
> In addition, this procedure does not apply to 64-bit ARM systems.

Prerequisites

- Virtualization is installed and enabled on your system.
- You have administrator access to the source host and the destination host for the migration.

Procedure

1. On the source host, obtain its CPU features and paste them into a new XML file, such as **domCaps-CPUs.xml**.

   ```
   # virsh domcapabilities | xmllint --xpath "//cpu/mode[@name='host-model']" - > domCaps-CPUs.xml
   ```

2. In the XML file, replace the **<mode> </mode>** tags with **<cpu> </cpu>**.

3. Optional: Verify that the content of the **domCaps-CPUs.xml** file looks similar to the following:

   ```
   # cat domCaps-CPUs.xml

     <cpu>
         <model fallback="forbid">Skylake-Client-IBRS</model>
         <vendor>Intel</vendor>
         <feature policy="require" name="ss"/>
         <feature policy="require" name="vmx"/>
         <feature policy="require" name="pdcm"/>
         <feature policy="require" name="hypervisor"/>
         <feature policy="require" name="tsc_adjust"/>
         <feature policy="require" name="clflushopt"/>
         <feature policy="require" name="umip"/>
         <feature policy="require" name="md-clear"/>
         <feature policy="require" name="stibp"/>
         <feature policy="require" name="arch-capabilities"/>
         <feature policy="require" name="ssbd"/>
         <feature policy="require" name="xsaves"/>
         <feature policy="require" name="pdpe1gb"/>
         <feature policy="require" name="invtsc"/>
   ```

```
    <feature policy="require" name="ibpb"/>
    <feature policy="require" name="ibrs"/>
    <feature policy="require" name="amd-stibp"/>
    <feature policy="require" name="amd-ssbd"/>
    <feature policy="require" name="rsba"/>
    <feature policy="require" name="skip-l1dfl-vmentry"/>
    <feature policy="require" name="pschange-mc-no"/>
    <feature policy="disable" name="hle"/>
    <feature policy="disable" name="rtm"/>
</cpu>
```

4. On the destination host, use the following command to obtain its CPU features:

```
# virsh domcapabilities | xmllint --xpath "//cpu/mode[@name='host-model']" -

  <mode name="host-model" supported="yes">
        <model fallback="forbid">IvyBridge-IBRS</model>
        <vendor>Intel</vendor>
        <feature policy="require" name="ss"/>
        <feature policy="require" name="vmx"/>
        <feature policy="require" name="pdcm"/>
        <feature policy="require" name="pcid"/>
        <feature policy="require" name="hypervisor"/>
        <feature policy="require" name="arat"/>
        <feature policy="require" name="tsc_adjust"/>
        <feature policy="require" name="umip"/>
        <feature policy="require" name="md-clear"/>
        <feature policy="require" name="stibp"/>
        <feature policy="require" name="arch-capabilities"/>
        <feature policy="require" name="ssbd"/>
        <feature policy="require" name="xsaveopt"/>
        <feature policy="require" name="pdpe1gb"/>
        <feature policy="require" name="invtsc"/>
        <feature policy="require" name="ibpb"/>
        <feature policy="require" name="amd-ssbd"/>
        <feature policy="require" name="skip-l1dfl-vmentry"/>
        <feature policy="require" name="pschange-mc-no"/>
  </mode>
```

5. Add the obtained CPU features from the destination host to the **domCaps-CPUs.xml** file on the source host. Again, replace the **<mode> </mode>** tags with **<cpu> </cpu>** and save the file.

6. Optional: Verify that the XML file now contains the CPU features from both hosts.

```
# cat domCaps-CPUs.xml

  <cpu>
      <model fallback="forbid">Skylake-Client-IBRS</model>
      <vendor>Intel</vendor>
      <feature policy="require" name="ss"/>
      <feature policy="require" name="vmx"/>
      <feature policy="require" name="pdcm"/>
      <feature policy="require" name="hypervisor"/>
      <feature policy="require" name="tsc_adjust"/>
      <feature policy="require" name="clflushopt"/>
```

```
        <feature policy="require" name="umip"/>
        <feature policy="require" name="md-clear"/>
        <feature policy="require" name="stibp"/>
        <feature policy="require" name="arch-capabilities"/>
        <feature policy="require" name="ssbd"/>
        <feature policy="require" name="xsaves"/>
        <feature policy="require" name="pdpe1gb"/>
        <feature policy="require" name="invtsc"/>
        <feature policy="require" name="ibpb"/>
        <feature policy="require" name="ibrs"/>
        <feature policy="require" name="amd-stibp"/>
        <feature policy="require" name="amd-ssbd"/>
        <feature policy="require" name="rsba"/>
        <feature policy="require" name="skip-l1dfl-vmentry"/>
        <feature policy="require" name="pschange-mc-no"/>
        <feature policy="disable" name="hle"/>
        <feature policy="disable" name="rtm"/>
    </cpu>
    <cpu>
        <model fallback="forbid">IvyBridge-IBRS</model>
        <vendor>Intel</vendor>
        <feature policy="require" name="ss"/>
        <feature policy="require" name="vmx"/>
        <feature policy="require" name="pdcm"/>
        <feature policy="require" name="pcid"/>
        <feature policy="require" name="hypervisor"/>
        <feature policy="require" name="arat"/>
        <feature policy="require" name="tsc_adjust"/>
        <feature policy="require" name="umip"/>
        <feature policy="require" name="md-clear"/>
        <feature policy="require" name="stibp"/>
        <feature policy="require" name="arch-capabilities"/>
        <feature policy="require" name="ssbd"/>
        <feature policy="require" name="xsaveopt"/>
        <feature policy="require" name="pdpe1gb"/>
        <feature policy="require" name="invtsc"/>
        <feature policy="require" name="ibpb"/>
        <feature policy="require" name="amd-ssbd"/>
        <feature policy="require" name="skip-l1dfl-vmentry"/>
        <feature policy="require" name="pschange-mc-no"/>
    </cpu>
```

7. Use the XML file to calculate the CPU feature baseline for the VM you intend to migrate.

```
# virsh hypervisor-cpu-baseline domCaps-CPUs.xml

    <cpu mode='custom' match='exact'>
      <model fallback='forbid'>IvyBridge-IBRS</model>
      <vendor>Intel</vendor>
      <feature policy='require' name='ss'/>
      <feature policy='require' name='vmx'/>
      <feature policy='require' name='pdcm'/>
      <feature policy='require' name='pcid'/>
      <feature policy='require' name='hypervisor'/>
      <feature policy='require' name='arat'/>
      <feature policy='require' name='tsc_adjust'/>
    <feature policy='require' name='umip'/>
    <feature policy='require' name='md-clear'/>
    <feature policy='require' name='stibp'/>
    <feature policy='require' name='arch-capabilities'/>
    <feature policy='require' name='ssbd'/>
    <feature policy='require' name='xsaveopt'/>
    <feature policy='require' name='pdpe1gb'/>
    <feature policy='require' name='invtsc'/>
    <feature policy='require' name='ibpb'/>
    <feature policy='require' name='amd-ssbd'/>
    <feature policy='require' name='skip-l1dfl-vmentry'/>
    <feature policy='require' name='pschange-mc-no'/>
  </cpu>
```

8. Open the XML configuration of the VM you intend to migrate, and replace the contents of the **<cpu>** section with the settings obtained in the previous step.

   ```
   # virsh edit <vm_name>
   ```

9. If the VM is running, shut down the VM and start it again.

   ```
   # virsh shutdown <vm_name>

   # virsh start <vm_name>
   ```

Next steps

- Sharing virtual machine disk images with other hosts
- Migrating a virtual machine by using the command line
- Live-migrating a virtual machine by using the web console

12.10. SUPPORTED HOSTS FOR VIRTUAL MACHINE MIGRATION

For the virtual machine (VM) migration to work properly and be supported by Red Hat, the source and destination hosts must be specific RHEL versions and machine types. The following table shows supported VM migration paths.

Table 12.2. Live migration compatibility

Migration method	Release type	Future version example	Support status
Forward	Minor release	9.3 → 9.7	On supported RHEL 9 systems: Supported for machine type **q35**.
Forward	Major release	8.x → 9.7	On supported RHEL 9 systems: Supported for machine type **q35**.

Migration method	Release type	Future version example	Support status
Forward	Major release	9.7 → 10.x	On supported RHEL 9 systems: Supported for machine type **q35**.
Backward	Minor release	9.7 → 9.6	On supported RHEL 9 systems: Supported for machine type **q35**.
Backward	Major release	9.7 → 8.x	On supported RHEL 9 systems: Supported for machine type **q35**.
Backward	Major release	10.1 → 9.7	On supported RHEL 9 systems: Supported for machine type **q35**.

NOTE

Support level is different for other virtualization solutions provided by Red Hat, including RHOSP and OpenShift Virtualization.

CHAPTER 13. SAVING AND RESTORING VIRTUAL MACHINE STATE BY USING SNAPSHOTS

To save the current state of a virtual machine (VM), you can create a *snapshot* of the VM. Afterwards, you can revert to the snapshot to return the VM to the saved state.

A VM snapshot contains the disk image of the VM. If you create a snapshot from a running VM (also known as a *live snapshot*), the snapshot also contains the memory state of the VM, which includes running processes and applications.

Creating snapshots can be useful, for example, for the following tasks:

- Saving a clean state of the guest operating system
- Ensuring that you have a restore point before performing a potentially destructive operation on the VM

13.1. SUPPORT LIMITATIONS FOR VIRTUAL MACHINE SNAPSHOTS

Red Hat supports the snapshot functionality for virtual machines (VMs) on RHEL only when you use **external** snapshots. Currently, external snapshots are created on RHEL only when all of the following requirements are met:

- Your host is using RHEL 9.4 or later.
- The VM is using file-based storage.
- You create the VM snapshot only in one of the following scenarios:
  - The VM is shut-down.
  - If the VM is running, you use the **--disk-only --quiesce** options or the **--live --memspec** options.

Most other configurations create **internal** snapshots, which are deprecated in RHEL 9. Internal snapshots might work for your use case, but Red Hat does not provide full testing and support for them.

> **WARNING**
>
> Do not use internal snapshots in production environments.

To ensure that a snapshot is supported, display the XML configuration of the snapshot and check the snapshot type and storage:

```
# virsh snapshot-dumpxml <vm-name> <snapshot-name>
```

- Example output of a supported snapshot:

  ```
  <domainsnapshot>
   <name>sample-snapshot-name-1<name>
  ```

```
  <state>shutoff</state>
  <creationTime>1706658764</creationTime>
  <memory snapshot='no'/>
  <disks>
    <disk name='vda' snapshot='external' type='file'>
      <driver type='qcow2'/>
      <source file='/var/lib/libvirt/images/vm-name.sample-snapshot-name-1'/>
    </disk>
  </disks>
  <domain type='kvm'>
  [...]
```

- Example output of an unsupported snapshot:

```
<domainsnapshot>
  <name>sample-snapshot-name-2</name>
  <state>running</state>
  <creationTime>1653396424</creationTime>
  <memory snapshot='internal'/>
  <disks>
    <disk name='vda' snapshot='internal'/>
    <disk name='sda' snapshot='no'/>
  </disks>
  <domain type='kvm'>
  [...]
```

13.2. CREATING VIRTUAL MACHINE SNAPSHOTS BY USING THE COMMAND LINE

To save the state of a virtual machine (VM) in a snapshot, you can use the **virsh snapshot-create-as** command.

Prerequisites

- Your host is using RHEL 9.4 or later.
- The VM uses file-based storage. To check whether this is the case, use the following command and ensure that for the **disk** device, it displays **disk type** as **file**:

```
# virsh dumpxml <vm-name> | grep "disk type"
    <disk type='file' device='disk'>
    <disk type='file' device='cdrom'>
```

- If you want to create a VM snapshot that includes the memory of a running VM, you must have sufficient disk space to store the memory of the VM.
  - The minimum recommended space for saving the memory of a VM is equal to the VM's assigned RAM. For example, saving the memory of a VM with 32 GB RAM requires up to 32 GB of disk space.
  - If the VM is under heavy I/O load, significant additional disk space might be required.
  - If the VM has assigned VFIO passthrough devices, additional disk space might be required.

- If a snapshot is created without pausing the VM, additional disk space might be required.

> **WARNING**
>
> Red Hat recommends not saving the memory of a running VMs that is under very high workload or that uses VFIO passthrough devices. Saving the memory of such VMs might fill up the host disk and degrade the system. Instead, consider creating snapshots without memory for such VMs.
>
> In addition, note that not all VFIO devices are capable of creating snapshot with memory. Currently, creating a snapshot with memory works correctly only in the following situations:
>
> - The attached VFIO device is a Mellanox VF with the migration capability enabled.
> - The attached VFIO device is an NVIDIA vGPU with the migration capability enabled.

Procedure

- To create a VM snapshot with the required parameters, use the **virsh snapshot-create-as** command.

```
# virsh snapshot-create-as <vm-name> <snapshot-name> <optional-description>
<additional-parameters>
```

  - To create a snapshot of a shut-down VM, use the **--disk-only** parameter. For example, the following command creates **Snapshot1** from the current disk-state of the shut-down **Testguest1** VM:

```
# virsh snapshot-create-as Testguest1 Snapshot1 --disk-only
Domain snapshot Snapshot1 created.
```

  - To create a snapshot that saves the disk-state of a running VM but not its memory, use the **--disk-only --quiesce** parameters. For example, the following command creates **Snapshot2** from the current disk state of the running **Testguest2** VM, with the description **clean system install**:

```
# virsh snapshot-create-as Testguest2 Snapshot2 "clean system install" --disk-only --
quiesce
Domain snapshot Snapshot2 created.
```

  - To create a snapshot that pauses a running VM and saves its disk-state and memory, use the **--memspec** parameter. For example, the following command pauses the **Testguest3** VM and creates **Snapshot3** from the current disk and memory state of the VM. The VM memory is saved in the **/var/lib/libvirt/images/saved_memory.img** file. When the snapshot is complete, the VM automatically resumes operation.

```
# virsh snapshot-create-as Testguest3 Snapshot3 --memspec
/var/lib/libvirt/images/saved_memory.img
Domain snapshot Snapshot3 created.
```

Pausing the VM during the snapshot process creates downtime, but might work more reliably than creating a live snapshot of a running VM (by using the **--live** option), especially for VMs under a heavy load.

- To create a snapshot that saves the disk-state of a running VM as well as its live memory, use the **--live --memspec** parameters. For example, the following command creates **Snapshot4** from the current disk and memory state of the running **Testguest4** VM, and saves the memory state in the **/var/lib/libvirt/images/saved_memory2.img** file.

```
# virsh snapshot-create-as Testguest4 Snapshot4 --live --memspec
/var/lib/libvirt/images/saved_memory2.img
Domain snapshot Snapshot4 created.
```

WARNING

Saving the memory of a VM in a snapshot saves the state of the running processes in the guest operating system of the VM. However, when you revert to such a snapshot, the processes might fail due to a variety of factors, such as loss of network connectivity or unsynchronized system time.

Verification

1. List the snapshots associated with the specified VM:

```
# virsh snapshot-list <Testguest1>

 Name                Creation Time               State
--------------------------------------------------------------
Snapshot1            2024-01-30 18:34:58 +0100   shutoff
```

2. Verify that the snapshot has been created as *external*:

```
# virsh snapshot-dumpxml <Testguest1> <Snapshot1> | grep external

  <disk name='vda' snapshot='external' type='file'>
```

If the output of this command includes **snapshot='external'**, the snapshot is external and therefore fully supported by Red Hat.

Next steps

- Reverting to a VM snapshot by using the CLI
- Reverting to a VM snapshot by using the web console

Additional resources

- Upstream libvirt information on snapshot metadata
- **virsh** man page on your system

13.3. CREATING VIRTUAL MACHINE SNAPSHOTS BY USING THE WEB CONSOLE

To save the state of a virtual machine (VM) in a snapshot, you can use the RHEL 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 .
- Your host is using RHEL 9.4 or later.
- The web console VM plug-in is installed on your system.
- The VM uses file-based storage. To ensure that this is the case, perform the following steps:
  a. In the **Virtual machines** interface of the web console, click the VM of which you want to create a snapshot.
  b. In the **Disks** pane of the management overview, check the **Source** column of the listed devices. In all devices that list a source, this source must be **File**.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual machines** interface of the web console, click the VM of which you want to create a snapshot.
   A management overview of the VM opens.
3. In the **Snapshots** pane of the management overview, click the **Create snapshot** button.
4. Enter a name for the snapshot, and optionally a description.
5. Click **Create**.

Verification

1. To ensure that creating the snapshot has succeeded, check that the snapshot is now listed in the **Snapshots** pane of the VM.
2. Verify that the snapshot has been created as *external*. To do so, use the following command on the command line of the host:

```
# virsh snapshot-dumpxml <Testguest1> <Snapshot1> | grep external

  <disk name='vda' snapshot='external' type='file'>
```

If the output of this command includes **snapshot='external'**, the snapshot is external and therefore supported by Red Hat.

Next steps

- Reverting to a VM snapshot by using the web console
- Reverting to a VM snapshot by using the command line

13.4. REVERTING TO A VIRTUAL MACHINE SNAPSHOT BY USING THE COMMAND LINE

To return a virtual machine (VM) to the state saved in a snapshot, you can use the command-line-interface (CLI).

Prerequisites

- A snapshot of the VM is available, which you have previously created in the web console or by using the command line.
- Optional: You have created a snapshot of the current state of the VM. If you revert to a previous snapshot without saving the current state, changes performed on the VM since the last snapshot will be lost.

Procedure

- Use the **virsh snapshot-revert** utility and specify the name of the VM and the name of the snapshot to which you want to revert. For example:

```
# virsh snapshot-revert Testguest2 clean-install
Domain snapshot clean-install reverted
```

Verification

- Display the currently active snapshot for the reverted VM:

```
# virsh snapshot-current Testguest2 --name
clean-install
```

13.5. REVERTING TO A VIRTUAL MACHINE SNAPSHOT BY USING THE WEB CONSOLE

To return a virtual machine (VM) to the state saved in a snapshot, you can use the RHEL 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 web console VM plug-in is installed on your system.
- A snapshot of the VM is available, which you have previously created in the web console or by using the command line.
- Optional: You have created a snapshot of the current state of the VM. If you revert to a previous snapshot without saving the current state, changes performed on the VM since the last snapshot will be lost.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual machines** interface of the web console, click the VM whose state you want to revert.
   A management overview of the VM opens.
3. In the **Snapshots** pane of the management overview, click the **Revert** button next to the snapshot to which you want to revert.
4. Wait until the revert operation finishes. Depending on the size of the snapshot and how different it is from the current state, this might take up to several minutes.

Verification

- In the **Snapshots** pane, if a green check symbol now displays on the left side of the selected snapshot, you have successfully reverted to it.

13.6. DELETING VIRTUAL MACHINE SNAPSHOTS BY USING THE COMMAND LINE

When a virtual machine (VM) snapshot is no longer useful for you, you can delete it on the command line to free up the disk space that it uses.

Prerequisites

- Optional: A child snapshot exists for the snapshot you want to delete.
  A child snapshot is created automatically when you have an active snapshot and create a new snapshot. If you delete a snapshot that does not have any children, you will lose any changes saved in the snapshot after it was created from its parent snapshot.

  To view the parent-child structure of snapshots in a VM, use the **virsh snapshot-list --tree** command. The following example shows **Latest-snapshot** as a child of **Redundant-snapshot**.

  ```
  # virsh snapshot-list --tree <vm-name>

  Clean-install-snapshot
    |
  ```

```
  +- Redundant-snapshot
      |
      +- Latest-snapshot
```

Procedure

- Use the **virsh snapshot-delete** command to delete the snapshot. For example, the following command deletes **Redundant-snapshot** from the **Testguest1** VM:

  ```
  # virsh snapshot-delete Testguest1 Redundant-snapshot
  Domain snapshot Redundant-snapshot deleted
  ```

Verification

- To ensure that the snapshot that you deleted is no longer present, display the existing snapshots of the impacted VM and their parent-child structure:

  ```
  # virsh snapshot-list --tree <Testguest1>

  Clean-install-snapshot
    |
    +- Latest-snapshot
  ```

  In this example, **Redundant-snapshot** has been deleted and **Latest-snapshot** has become the child of **Clean-install-snapshot**.

13.7. DELETING VIRTUAL MACHINE SNAPSHOTS BY USING THE WEB CONSOLE

When a virtual machine (VM) snapshot is no longer useful for you, you can delete it in the web console to free up the disk space that it uses.

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 web console VM plug-in is installed on your system .
- Optional: A child snapshot exists for the snapshot you want to delete.
  A child snapshot is created automatically when you have an active snapshot and create a new snapshot. If you delete a snapshot that does not have any children, you will lose any changes saved in the snapshot after it was created from its parent snapshot.

  To check that the snapshot has a child, confirm that the snapshot is listed in the **Parent snapshot** column of the **Snapshots** in the web console overview of the VM.

Procedure

1. In the **Virtual machines** interface of the web console, click the VM whose snapshot you want to delete.
   A management overview of the VM opens.

2. In the **Snapshots** pane of the management overview, click the **Delete** button next to the snapshot that you want to delete.

3. Wait until the delete operation finishes. Depending on the size of the snapshot, this might take up to several minutes.

Verification

- If the snapshot no longer appears in the **Snapshots** pane, it has been deleted successfully.

CHAPTER 14. MANAGING VIRTUAL DEVICES

One of the most effective ways to manage the functionality, features, and performance of a virtual machine (VM) is to adjust its *virtual devices*.

The following sections provide a general overview of what virtual devices are, and instructions on how to manage them using the CLI or the web console.

14.1. HOW VIRTUAL DEVICES WORK

Just like physical machines, virtual machines (VMs) require specialized devices to provide functions to the system, such as processing power, memory, storage, networking, or graphics. Physical systems usually use hardware devices for these purposes. However, because VMs work as software implements, they need to use software abstractions of such devices instead, referred to as *virtual devices*.

The basics

Virtual devices attached to a VM can be configured when creating the VM, and can also be managed on an existing VM. Generally, virtual devices can be attached or detached from a VM only when the VM is shut off, but some can be added or removed when the VM is running. This feature is referred to as device *hot plug* and *hot unplug*.

When creating a new VM, **libvirt** automatically creates and configures a default set of essential virtual devices, unless specified otherwise by the user. These are based on the host system architecture and machine type, and usually include:

- the CPU
- memory
- a keyboard
- a network interface controller (NIC)
- various device controllers
- a video card
- a sound card

To manage virtual devices after the VM is created, use the command line (CLI). However, to manage virtual storage devices and NICs, you can also use the RHEL 9 web console.

Performance or flexibility

For some types of devices, RHEL 9 supports multiple implementations, often with a trade-off between performance and flexibility.

For example, the physical storage used for virtual disks can be represented by files in various formats, such as **qcow2** or **raw**, and presented to the VM by using a variety of controllers:

- an emulated controller
- **virtio-scsi**
- **virtio-blk**

An emulated controller is slower than a **virtio** controller, because **virtio** devices are designed specifically for virtualization purposes. On the other hand, emulated controllers make it possible to run operating systems that have no drivers for **virtio** devices. Similarly, **virtio-scsi** offers a more complete support for SCSI commands, and makes it possible to attach a larger number of disks to the VM. Finally, **virtio-blk** provides better performance than both **virtio-scsi** and emulated controllers, but a more limited range of use-cases. For example, attaching a physical disk as a LUN device to a VM is not possible when using **virtio-blk**.

For more information about types of virtual devices, see Types of virtual devices.

14.2. TYPES OF VIRTUAL DEVICES

Virtualization in RHEL 9 can present several distinct types of virtual devices that you can attach to virtual machines (VMs):

Emulated devices

Emulated devices are software implementations of widely used physical devices. Drivers designed for physical devices are also compatible with emulated devices. Therefore, emulated devices can be used very flexibly.
However, since they need to faithfully emulate a particular type of hardware, emulated devices may suffer a significant performance loss compared with the corresponding physical devices or more optimized virtual devices.

The following types of emulated devices are supported:

- Virtual CPUs (vCPUs), with a large choice of CPU models available. The performance impact of emulation depends significantly on the differences between the host CPU and the emulated vCPU.
- Emulated system components, such as PCI bus controllers.
- Emulated storage controllers, such as SATA, SCSI or even IDE.
- Emulated sound devices, such as ICH9, ICH6 or AC97.
- Emulated graphics cards, such as VGA cards.
- Emulated network devices, such as rtl8139.

Paravirtualized devices

Paravirtualization provides a fast and efficient method for exposing virtual devices to VMs. Paravirtualized devices expose interfaces that are designed specifically for use in VMs, and thus significantly increase device performance. RHEL 9 provides paravirtualized devices to VMs by using the *virtio* API as a layer between the hypervisor and the VM. The drawback of this approach is that it requires a specific device driver in the guest operating system.
It is recommended to use paravirtualized devices instead of emulated devices for VM whenever possible, notably if they are running I/O intensive applications. Paravirtualized devices decrease I/O latency and increase I/O throughput, in some cases bringing them very close to bare-metal performance. Other paravirtualized devices also add functionality to VMs that is not otherwise available.

The following types of paravirtualized devices are supported:

- The paravirtualized network device (**virtio-net**).

- Paravirtualized storage controllers:
  - **virtio-blk** - provides block device emulation.
  - **virtio-scsi** - provides more complete SCSI emulation.
- The paravirtualized clock.
- The paravirtualized serial device (**virtio-serial**).
- The balloon device (**virtio-balloon**), used to dynamically distribute memory between a VM and its host.
- The paravirtualized random number generator (**virtio-rng**).

Physically shared devices

Certain hardware platforms enable VMs to directly access various hardware devices and components. This process is known as *device assignment* or *passthrough*.
When attached in this way, some aspects of the physical device are directly available to the VM as they would be to a physical machine. This provides superior performance for the device when used in the VM. However, devices physically attached to a VM become unavailable to the host, and also cannot be migrated.

Nevertheless, some devices can be *shared* across multiple VMs. For example, a single physical device can in certain cases provide multiple *mediated devices*, which can then be assigned to distinct VMs.

The following types of passthrough devices are supported:

- USB, PCI, and SCSI passthrough - expose common industry standard buses directly to VMs in order to make their specific features available to guest software.
- Single-root I/O virtualization (SR-IOV) - a specification that enables hardware-enforced isolation of PCI Express resources. This makes it safe and efficient to partition a single physical PCI resource into virtual PCI functions. It is commonly used for network interface cards (NICs).
- N_Port ID virtualization (NPIV) - a Fibre Channel technology to share a single physical host bus adapter (HBA) with multiple virtual ports.
- GPUs and vGPUs - accelerators for specific kinds of graphic or compute workloads. Some GPUs can be attached directly to a VM, while certain types also offer the ability to create virtual GPUs (vGPUs) that share the underlying physical hardware.

NOTE

Some devices of these types might be unsupported or not compatible with RHEL. If you require assistance with setting up virtual devices, consult Red Hat support.

14.3. MANAGING DEVICES ATTACHED TO VIRTUAL MACHINES BY USING THE CLI

To modify the functionality of your virtual machine (VM), you can manage the devices attached to your VM by using the command line (CLI).

14.3.1. Attaching devices to virtual machines

You can add a specific functionality to your virtual machines (VMs) by attaching a new virtual device.

The following procedure creates and attaches virtual devices to your virtual machines (VMs) by using the command line (CLI). Some devices can also be attached to VMs using the RHEL web console .

For example, you can increase the storage capacity of a VM by attaching a new virtual disk device to it.

Prerequisites

- Obtain the required options for the device you intend to attach to a VM. To see the available options for a specific device, use the **virt-xml --*device*=?** command. For example:

  ```
  # virt-xml --network=?
  --network options:
  [...]
  address.unit
  boot_order
  clearxml
  driver_name
  [...]
  ```

Procedure

1. To attach a device to a VM, use the **virt-xml --add-device** command, including the definition of the device and the required options:

   - For example, the following command creates a 20GB *newdisk* qcow2 disk image in the **/var/lib/libvirt/images/** directory, and attaches it as a virtual disk to the running *testguest* VM on the next start-up of the VM:

     ```
     # virt-xml testguest --add-device --disk
     /var/lib/libvirt/images/newdisk.qcow2,format=qcow2,size=20
     Domain 'testguest' defined successfully.
     Changes will take effect after the domain is fully powered off.
     ```

   - The following attaches a USB flash drive, attached as device 004 on bus 002 on the host, to the *testguest2* VM while the VM is running:

     ```
     # virt-xml testguest2 --add-device --update --hostdev 002.004
     Device hotplug successful.
     Domain 'testguest2' defined successfully.
     ```

     The bus-device combination for defining the USB can be obtained by using the **lsusb** command.

Verification

To verify the device has been added, do any of the following:

- Use the **virsh dumpxml** command and see if the device's XML definition has been added to the **<devices>** section in the VM's XML configuration.
  For example, the following output shows the configuration of the *testguest* VM and confirms that the 002.004 USB flash disk device has been added.

```
# virsh dumpxml testguest
[...]
<hostdev mode='subsystem' type='usb' managed='yes'>
  <source>
    <vendor id='0x4146'/>
    <product id='0x902e'/>
    <address bus='2' device='4'/>
  </source>
  <alias name='hostdev0'/>
  <address type='usb' bus='0' port='3'/>
</hostdev>
[...]
```

- Run the VM and test if the device is present and works properly.

Additional resources

- The **man virt-xml** command

14.3.2. Modifying devices attached to virtual machines

You can change the functionality of your virtual machines (VMs) by editing a configuration of the attached virtual devices. For example, if you want to optimize the performance of your VMs, you can change their virtual CPU models to better match the CPUs of the hosts.

The following procedure provides general instructions for modifying virtual devices by using the command line (CLI). Some devices attached to your VM, such as disks and NICs, can also be modified using the RHEL 9 web console.

Prerequisites

- Obtain the required options for the device you intend to attach to a VM. To see the available options for a specific device, use the **virt-xml --*device*=?** command. For example:

```
# virt-xml --network=?
--network options:
[...]
address.unit
boot_order
clearxml
driver_name
[...]
```

- Optional: Back up the XML configuration of your VM by using **virsh dumpxml *vm-name*** and sending the output to a file. For example, the following backs up the configuration of your *testguest1* VM as the **testguest1.xml** file:

```
# virsh dumpxml testguest1 > testguest1.xml
# cat testguest1.xml
<domain type='kvm' xmlns:qemu='http://libvirt.org/schemas/domain/qemu/1.0'>
  <name>testguest1</name>
  <uuid>ede29304-fe0c-4ca4-abcd-d246481acd18</uuid>
  [...]
</domain>
```

Procedure

1. Use the **virt-xml --edit** command, including the definition of the device and the required options:
   For example, the following clears the *<cpu>* configuration of the shut-off *testguest* VM and sets it to *host-model*:

   ```
   # virt-xml testguest --edit --cpu host-model,clearxml=yes
   Domain 'testguest' defined successfully.
   ```

Verification

To verify the device has been modified, do any of the following:

- Run the VM and test if the device is present and reflects the modifications.

- Use the **virsh dumpxml** command and see if the device's XML definition has been modified in the VM's XML configuration.
  For example, the following output shows the configuration of the *testguest* VM and confirms that the CPU mode has been configured as *host-model*.

  ```
  # virsh dumpxml testguest
  [...]
  <cpu mode='host-model' check='partial'>
    <model fallback='allow'/>
  </cpu>
  [...]
  ```

Troubleshooting

- If modifying a device causes your VM to become unbootable, use the **virsh define** utility to restore the XML configuration by reloading the XML configuration file you backed up previously.

  ```
  # virsh define testguest.xml
  ```

NOTE

For small changes to the XML configuration of your VM, you can use the **virsh edit** command - for example **virsh edit testguest**. However, do not use this method for more extensive changes, as it is more likely to break the configuration in ways that could prevent the VM from booting.

Additional resources

- The **man virt-xml** command

14.3.3. Removing devices from virtual machines

You can change the functionality of your virtual machines (VMs) by removing a virtual device. For example, you can remove a virtual disk device from one of your VMs if it is no longer needed.

The following procedure demonstrates how to remove virtual devices from your virtual machines (VMs) by using the command line (CLI). Some devices, such as disks or NICs, can also be removed from VMs using the RHEL 9 web console .

Prerequisites

- Optional: Back up the XML configuration of your VM by using **virsh dumpxml *vm-name*** and sending the output to a file. For example, the following backs up the configuration of your *testguest1* VM as the **testguest1.xml** file:

```
# virsh dumpxml testguest1 > testguest1.xml
# cat testguest1.xml
<domain type='kvm' xmlns:qemu='http://libvirt.org/schemas/domain/qemu/1.0'>
  <name>testguest1</name>
  <uuid>ede29304-fe0c-4ca4-abcd-d246481acd18</uuid>
  [...]
</domain>
```

Procedure

1. Use the **virt-xml --remove-device** command, including a definition of the device. For example:

    - The following removes the storage device marked as *vdb* from the running *testguest* VM after it shuts down:

      ```
      # virt-xml testguest --remove-device --disk target=vdb
      Domain 'testguest' defined successfully.
      Changes will take effect after the domain is fully powered off.
      ```

    - The following immediately removes a USB flash drive device from the running *testguest2* VM:

      ```
      # virt-xml testguest2 --remove-device --update --hostdev type=usb
      Device hotunplug successful.
      Domain 'testguest2' defined successfully.
      ```

Troubleshooting

- If removing a device causes your VM to become unbootable, use the **virsh define** utility to restore the XML configuration by reloading the XML configuration file you backed up previously.

  ```
  # virsh define testguest.xml
  ```

Additional resources

- The **man virt-xml** command

14.4. MANAGING HOST DEVICES BY USING THE WEB CONSOLE

To modify the functionality of your virtual machine (VM), you can manage the host devices attached to your VM by using the RHEL 9 web console.

Host devices are physical devices that are attached to the host system. Based on your requirements, you can enable your VMs to directly access these hardware devices and components.

You can use the web console to:

- View devices
- Attach devices
- Remove devices

14.4.1. Viewing devices attached to virtual machines by using the web console

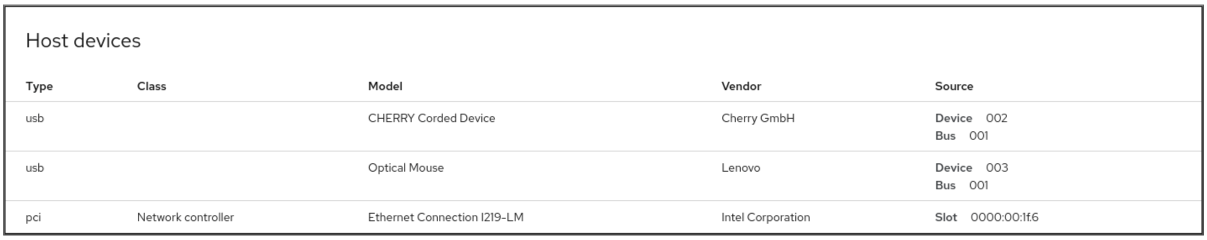
Before adding or modifying the devices attached to your virtual machine (VM), you may want to view the devices that are already attached to your VM. The following procedure provides instructions for viewing such devices by using the web console.

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 web console VM plug-in 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 **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with detailed information about the VM.
3. Scroll to the **Host devices** section.



Host devices

Type	Class	Model	Vendor	Source
usb		CHERRY Corded Device	Cherry GmbH	**Device** 002 **Bus** 001
usb		Optical Mouse	Lenovo	**Device** 003 **Bus** 001
pci	Network controller	Ethernet Connection I219-LM	Intel Corporation	**Slot** 0000:00:1f.6

Additional resources

- Managing virtual devices

14.4.2. Attaching devices to virtual machines by using the web console

To add specific functionalities to your virtual machine (VM), you can use the web console to attach host devices to the VM.

NOTE

Attaching multiple host devices at the same time does not work. You can attach only one device at a time.

For more information, see RHEL 9 Known Issues.

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 .
- If you are attaching PCI devices, ensure that the status of the **managed** attribute of the **hostdev** element is set to **yes**.

  NOTE

  When attaching PCI devices to your VM, do not omit the **managed** attribute of the **hostdev** element, or set it to **no**. If you do so, PCI devices cannot automatically detach from the host when you pass them to the VM. They also cannot automatically reattach to the host when you turn off the VM.

  As a consequence, the host may become unresponsive or shut down unexpectedly.

  You can find the status of the **managed** attribute in your VM's XML configuration. The following example opens the XML configuration of the **example-VM-1** VM.

  ```
  # virsh edit example-VM-1
  ```

- Back up important data from the VM.
- Optional: Back up the XML configuration of your VM. For example, to back up the **example-VM-1** VM:

  ```
  # virsh dumpxml example-VM-1 > example-VM-1.xml
  ```

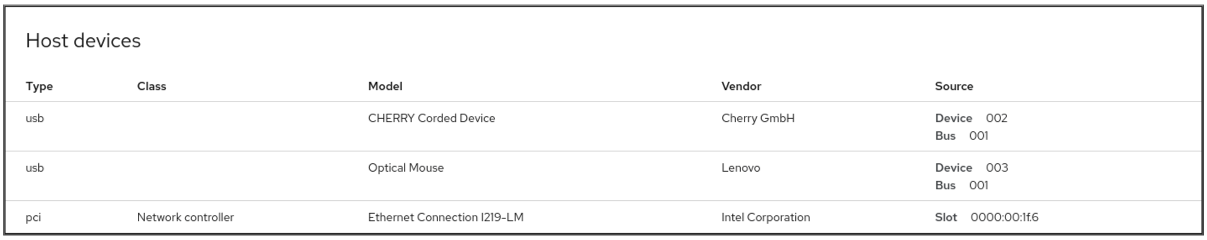
- The web console VM plug-in is installed on your system .

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the VM to which you want to attach a host device.
   A new page opens with an **Overview** section with basic information about the selected VM and a **Console** section to access the VM's graphical interface.
3. Scroll to **Host devices**.

   The **Host devices** section displays information about the devices attached to the VM as well

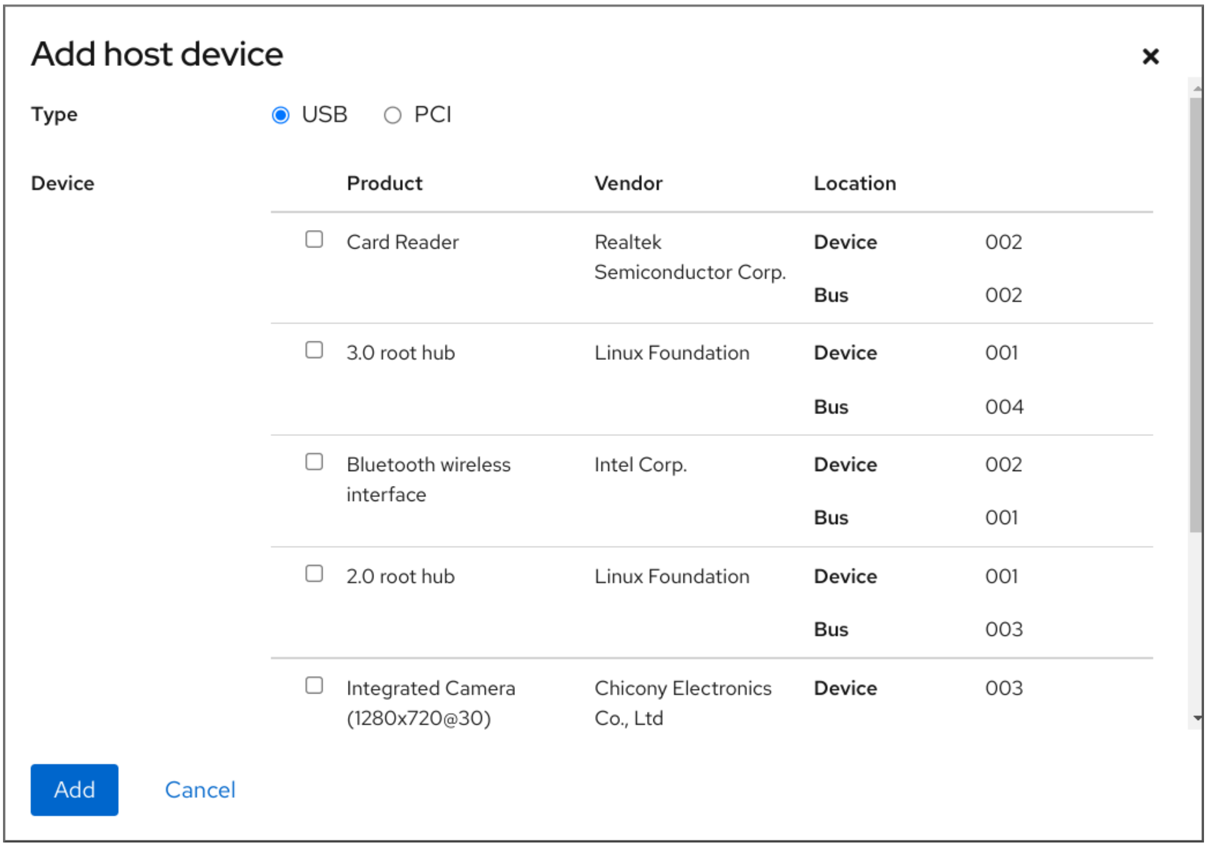
The **Host devices** section displays information about the devices attached to the VM as well as options to **Add** or **Remove** devices.



Host devices

Type	Class	Model	Vendor	Source
usb		CHERRY Corded Device	Cherry GmbH	**Device** 002 **Bus** 001
usb		Optical Mouse	Lenovo	**Device** 003 **Bus** 001
pci	Network controller	Ethernet Connection I219-LM	Intel Corporation	**Slot** 0000:00:1f.6

4. Click **Add host device**.
   The **Add host device** dialog appears.



Add host device

Type ● USB ○ PCI

Device

	Product	Vendor	Location	
□	Card Reader	Realtek Semiconductor Corp.	**Device** **Bus**	002 002
□	3.0 root hub	Linux Foundation	**Device** **Bus**	001 004
□	Bluetooth wireless interface	Intel Corp.	**Device** **Bus**	002 001
□	2.0 root hub	Linux Foundation	**Device** **Bus**	001 003
□	Integrated Camera (1280x720@30)	Chicony Electronics Co., Ltd	**Device**	003

5. Select the device you wish to attach to the VM.

6. Click **Add**
   The selected device is attached to the VM.

Verification

- Run the VM and check if the device appears in the **Host devices** section.

14.4.3. Removing devices from virtual machines by using the web console

To free up resources, modify the functionalities of your VM, or both, you can use the web console to modify the VM and remove host devices that are no longer required.

> **WARNING**
>
> Removing attached USB host devices by using the web console may fail because of incorrect correlation between the device and bus numbers of the USB device.
>
> For more information, see RHEL 9 Known Issues.
>
> As a workaround, remove the <hostdev> part of the USB device, from the XML configuration of VM by using the *virsh* utility. The following example opens the XML configuration of the **example-VM-1** VM:
>
> ```
> # virsh edit <example-VM-1>
> ```

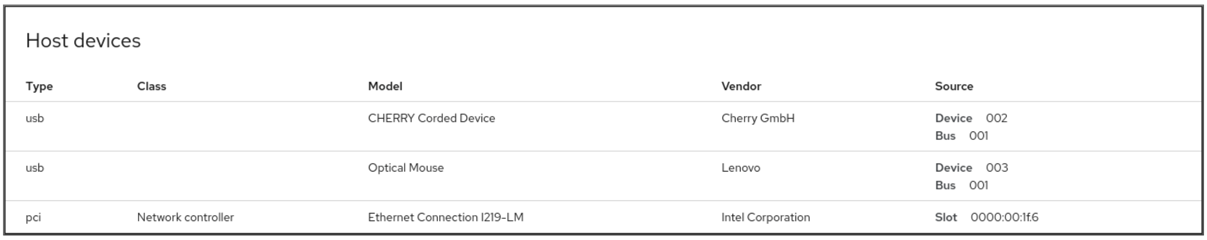
Prerequisites

- 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 web console VM plug-in is installed on your system .
- Optional: Back up the XML configuration of your VM by using **virsh dumpxml *example-VM-1*** and sending the output to a file. For example, the following backs up the configuration of your *testguest1* VM as the **testguest1.xml** file:

  ```
  # virsh dumpxml testguest1 > testguest1.xml
  # cat testguest1.xml
  <domain type='kvm' xmlns:qemu='http://libvirt.org/schemas/domain/qemu/1.0'>
    <name>testguest1</name>
    <uuid>ede29304-fe0c-4ca4-abcd-d246481acd18</uuid>
    [...]
  </domain>
  ```

Procedure

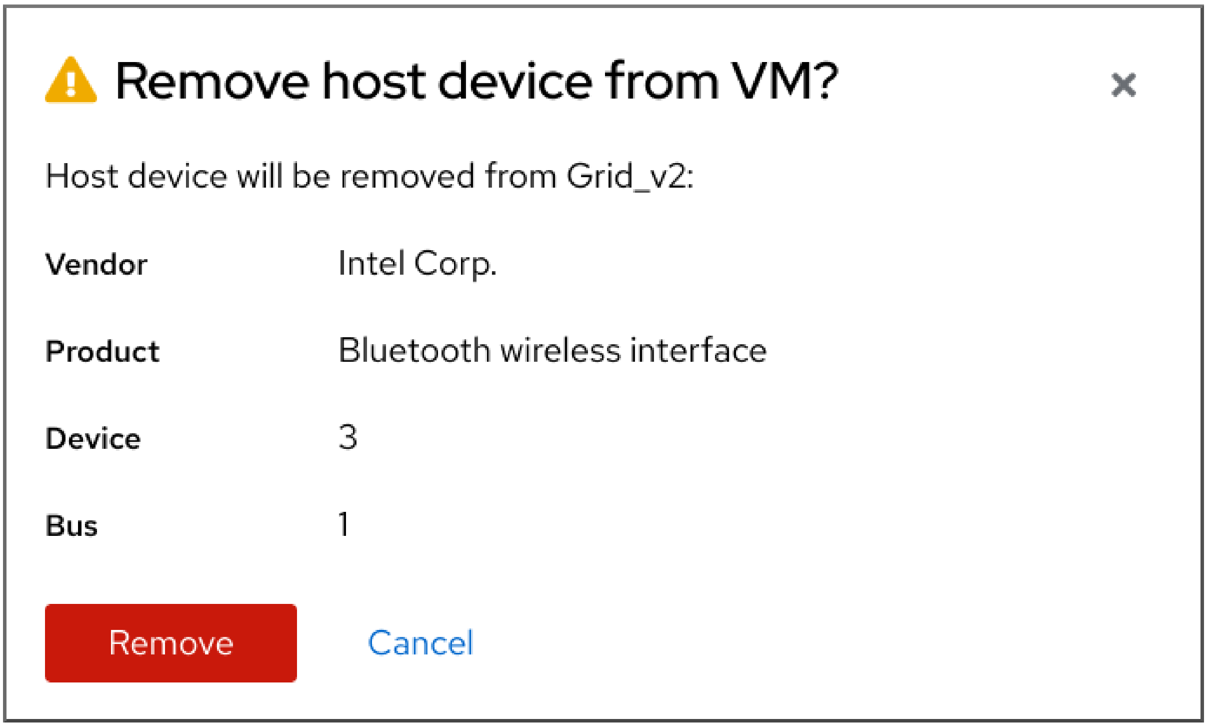
1. In the **Virtual Machines** interface, click the VM from which you want to remove a host device.
   A new page opens with an **Overview** section with basic information about the selected VM and a **Console** section to access the VM's graphical interface.
2. Scroll to **Host devices**.
   The **Host devices** section displays information about the devices attached to the VM as well as options to **Add** or **Remove** devices.



Host devices

Type	Class	Model	Vendor	Source
usb		CHERRY Corded Device	Cherry GmbH	**Device** 002 **Bus** 001
usb		Optical Mouse	Lenovo	**Device** 003 **Bus** 001
pci	Network controller	Ethernet Connection I219-LM	Intel Corporation	**Slot** 0000:00:1f.6

3. Click the **Remove** button next to the device you want to remove from the VM.
   A remove device confirmation dialog appears.



Remove host device from VM?

Host device will be removed from Grid_v2:

Vendor	Intel Corp.
Product	Bluetooth wireless interface
Device	3
Bus	1

4. Click **Remove**.
   The device is removed from the VM.

Troubleshooting

- If removing a host device causes your VM to become unbootable, use the **virsh define** utility to restore the XML configuration by reloading the XML configuration file you backed up previously.

```
# virsh define testguest1.xml
```

14.5. MANAGING VIRTUAL USB DEVICES

When using a virtual machine (VM), you can access and control a USB device, such as a flash drive or a web camera, that is attached to the host system. In this scenario, the host system passes control of the device to the VM. This is also known as a USB-passthrough.

14.5.1. Attaching USB devices to virtual machines

To attach a USB device to a virtual machine (VM), you can include the USB device information in the XML configuration file of the VM.

Prerequisites

- Ensure the device you want to pass through to the VM is attached to the host.

Procedure

1. Locate the bus and device values of the USB that you want to attach to the VM.
   For example, the following command displays a list of USB devices attached to the host. The device we will use in this example is attached on bus 001 as device 005.

   ```
   # lsusb
   [...]
   Bus 001 Device 003: ID 2567:0a2b Intel Corp.
   Bus 001 Device 005: ID 0407:6252 Kingston River 2.0
   [...]
   ```

2. Use the **virt-xml** utility along with the **--add-device** argument.
   For example, the following command attaches a USB flash drive to the **example-VM-1** VM.

   ```
   # virt-xml example-VM-1 --add-device --hostdev 001.005
   Domain 'example-VM-1' defined successfully.
   ```

NOTE

To attach a USB device to a running VM, add the **--update** argument to the previous command.

Verification

- Run the VM and test if the device is present and works as expected.
- Use the **virsh dumpxml** command to see if the device's XML definition has been added to the <devices> section in the VM's XML configuration file.

  ```
  # virsh dumpxml example-VM-1
  [...]
  <hostdev mode='subsystem' type='usb' managed='yes'>
    <source>
      <vendor id='0x0407'/>
      <product id='0x6252'/>
      <address bus='1' device='5'/>
    </source>
    <alias name='hostdev0'/>
    <address type='usb' bus='0' port='3'/>
  </hostdev>
  [...]
  ```

Additional resources

- **virt-xml (1)** man page on your system
- Attaching devices to virtual machines

14.5.2. Removing USB devices from virtual machines

To remove a USB device from a virtual machine (VM), you can remove the USB device information from the XML configuration of the VM.

Procedure

1. Locate the bus and device values of the USB that you want to remove from the VM.
   For example, the following command displays a list of USB devices attached to the host. The device we will use in this example is attached on bus 001 as device 005.

```
# lsusb
[...]
Bus 001 Device 003: ID 2567:0a2b Intel Corp.
Bus 001 Device 005: ID 0407:6252 Kingston River 2.0
[...]
```

2. Use the **virt-xml** utility along with the **--remove-device** argument.
   For example, the following command removes a USB flash drive, attached to the host as device 005 on bus 001, from the **example-VM-1** VM.

```
# virt-xml example-VM-1 --remove-device --hostdev 001.005
Domain 'example-VM-1' defined successfully.
```

NOTE

To remove a USB device from a running VM, add the **--update** argument to the previous command.

Verification

- Run the VM and check if the device has been removed from the list of devices.

Additional resources

- **virt-xml (1)** man page on your system
- Attaching devices to virtual machines

14.6. MANAGING VIRTUAL OPTICAL DRIVES

When using a virtual machine (VM), you can access information stored in an ISO image on the host. To do so, attach the ISO image to the VM as a virtual optical drive, such as a CD drive or a DVD drive.

14.6.1. Attaching optical drives to virtual machines

To attach an ISO image as a virtual optical drive, edit the XML configuration file of the virtual machine (VM) and add the new drive.

Prerequisites

- You must store and copy path of the ISO image on the host machine.

Procedure

- Use the **virt-xml** utility with the **--add-device** argument:
  For example, the following command attaches the **example-ISO-name** ISO image, stored in the **/home/username/Downloads** directory, to the **example-VM-name** VM.

  ```
  # virt-xml example-VM-name --add-device --disk /home/username/Downloads/example-ISO-name.iso,device=cdrom
  Domain 'example-VM-name' defined successfully.
  ```

Verification

- Run the VM and test if the device is present and works as expected.

Additional resources

- The **man virt-xml** command
- Attaching devices to virtual machines

14.6.2. Adding a CD-ROM to a running virtual machine by using the web console

You can use the web console to insert a CD-ROM to a running virtual machine (VM) without specifying the media.

Prerequisites

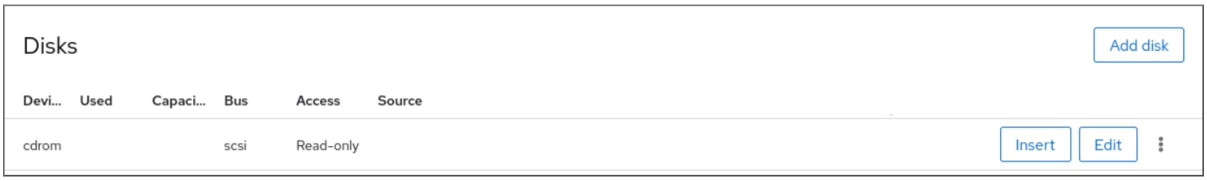
- You have installed the web console VM plug-in on your system .

Procedure

1. Shut down the VM.
2. Attach a virtual CD-ROM device without specifying a source image.

   ```
   # virt-xml vmname --add-device --disk target.dev=sda,device=cdrom
   ```

3. Run the VM.
4. Open the web console and in the **Virtual Machines** interface, click the VM to which you want to attach a CD-ROM.
5. Scroll to **Disks**.
   The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.
6. Click the **Insert** option for the **cdrom** device.



Disks

Devi...	Used	Capaci...	Bus	Access	Source
cdrom			scsi	Read-only	

7. Choose a **Source** for the file you want to attach:
   - **Custom Path**: The file is located in a custom directory on the host machine.

- **Use existing**: The file is located in the storage pools that you have created.

8. Click **Insert**.

Verification

- In the **Virtual Machines** interface, the file will appear under the **Disks** section.

14.6.3. Replacing ISO images in virtual optical drives

To replace an ISO image attached as a virtual optical drive to a virtual machine (VM), edit the XML configuration file of the VM and specify the replacement.

Prerequisites

- You must store the ISO image on the host machine.

- You must know the path to the ISO image.

Procedure

1. Locate the target device where the CD-ROM is attached to the VM. You can find this information in the VM's XML configuration file.
   For example, the following command displays the ***example-VM-name*** VM's XML configuration file, where the target device for CD-ROM is **sda**.

   ```
   # virsh dumpxml example-VM-name
   ...
   <disk>
     ...
     <source file='$(/home/username/Downloads/example-ISO-name.iso)'/>
     <target dev='sda' bus='sata'/>
     ...
   </disk>
   ...
   ```

2. Use the **virt-xml** utility with the **--edit** argument.
   For example, the following command replaces the **example-ISO-name** ISO image, attached to the **example-VM-name** VM at target **sda**, with the **example-ISO-name-2** ISO image stored in the **/dev/cdrom** directory.

   ```
   # virt-xml example-VM-name --edit target=sda --disk /dev/cdrom/example-ISO-name-2.iso
   Domain 'example-VM-name' defined successfully.
   ```

Verification

- Run the VM and test if the device is replaced and works as expected.

Additional resources

- The **man virt-xml** command

14.6.4. Removing ISO images from virtual optical drives

To remove an ISO image from a virtual optical drive attached to a virtual machine (VM), edit the XML configuration file of the VM.

Procedure

1. Locate the target device where the CD-ROM is attached to the VM. You can find this information in the VM's XML configuration file.
   For example, the following command displays the **example-VM-name** VM's XML configuration file, where the target device for CD-ROM is **sda**.

```
# virsh dumpxml example-VM-name
...
<disk>
  ...
  <source file='$(/home/username/Downloads/example-ISO-name.iso)'/>
  <target dev='sda' bus='sata'/>
  ...
</disk>
...
```

2. Use the **virt-xml** utility with the **--edit** argument.
   For example, the following command removes the **example-ISO-name** ISO image from the CD drive attached to the **example-VM-name** VM.

```
# virt-xml example-VM-name --edit target=sda --disk path=
Domain 'example-VM-name' defined successfully.
```

Verification

- Run the VM and check that image is no longer available.

Additional resources

- The **man virt-xml** command

14.6.5. Removing optical drives from virtual machines

To remove an optical drive attached to a virtual machine (VM), edit the XML configuration file of the VM.

Procedure

1. Locate the target device where the CD-ROM is attached to the VM. You can find this information in the VM's XML configuration file.
   For example, the following command displays the **example-VM-name** VM's XML configuration file, where the target device for CD-ROM is **sda**.

```
# virsh dumpxml example-VM-name
...
<disk type='file' device='cdrom'>
  <driver name='qemu' type='raw'/>
  <target dev='sda' bus='sata'/>
  ...
</disk>
...
```

2. Use the **virt-xml** utility with the **--remove-device** argument.
   For example, the following command removes the optical drive attached as target **sda** from the **example-VM-name** VM.

   ```
   # virt-xml example-VM-name --remove-device --disk target=sda
   Domain 'example-VM-name' defined successfully.
   ```

Verification

- Confirm that the device is no longer listed in the XML configuration file of the VM.

Additional resources

- The **man virt-xml** command

14.6.6. Removing a CD-ROM from a running virtual machine by using the web console

You can use the web console to eject a CD-ROM device from a running virtual machine (VM).

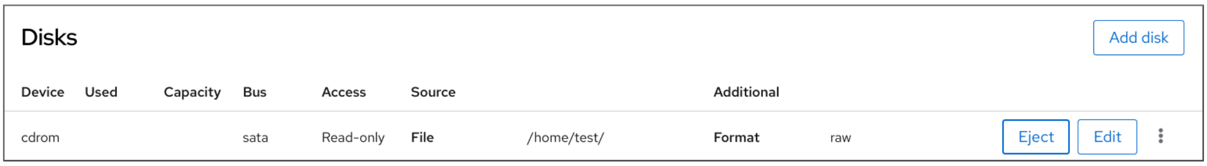
Prerequisites

- You have installed the web console VM plug-in on your system .

Procedure

1. In the **Virtual Machines** interface, click the VM from which you want to remove the CD-ROM.

2. Scroll to **Disks**.
   The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.



Disks

Device	Used	Capacity	Bus	Access	Source		Additional	
cdrom			sata	Read-only	File	/home/test/	Format	raw

3. Click the **Eject** option for the **cdrom** device.
   The **Eject media from VM?**dialog box opens.

4. Click **Eject**.

Verification

- In the **Virtual Machines** interface, the attached file is no longer displayed under the **Disks** section.

14.7. MANAGING PCI DEVICES IN VIRTUAL MACHINES

When using a virtual machine (VM), you can access and control a PCI device, such as a storage or network controller, that is attached to the host system. In this scenario, the host system passes control of the device to the VM. This is also known as a *PCI device assignment*, or *PCI passthrough*.

14.7.1. Attaching PCI devices to virtual machines

To use a PCI hardware device attached to your host in a virtual machine (VM), you can detach the device from the host and assign it to the VM. This is also known as *PCI passthrough*.

Prerequisites

- If your host is using the IBM Z architecture, the **vfio** kernel modules must be loaded on the host. To verify, use the following command:

  ```
  # lsmod | grep vfio
  ```

  The output must contain the following modules:

  - **vfio_pci**
  - **vfio_pci_core**
  - **vfio_iommu_type1**

PROCEDURE

The following steps describe generic PCI device assignment. For instructions on assigning specific types of PCI devices, see the following procedures:

- Attaching SR-IOV network devices to virtual machines
- Assigning a GPU to a virtual machine

1. Obtain the PCI address identifier of the device that you want to use. For example, if you want to use a NVME disk attached to the host, the following output showss it as device **0000:65:00.0**.

   ```
   # lspci -nkD

   0000:00:00.0 0600: 8086:a708 (rev 01)
    Subsystem: 17aa:230e
    Kernel driver in use: igen6_edac
    Kernel modules: igen6_edac
   0000:00:02.0 0300: 8086:a7a1 (rev 04)
    Subsystem: 17aa:230e
    Kernel driver in use: i915
    Kernel modules: i915, xe
   0000:00:04.0 1180: 8086:a71d (rev 01)
    Subsystem: 17aa:230e
    Kernel driver in use: proc_thermal_pci
    Kernel modules: processor_thermal_device_pci
   0000:00:05.0 0604: 8086:a74d (rev 01)
    Subsystem: 17aa:230e
   ```

```
 Kernel driver in use: pcieport
0000:00:07.0 0604: 8086:a76e (rev 01)
 Subsystem: 17aa:230e
 Kernel driver in use: pcieport
0000:65:00.0 0108: 144d:a822 (rev 01)
    DeviceName: PCIe SSD in Slot 0 Bay 2
    Subsystem: 1028:1fd9
    Kernel driver in use: nvme
    Kernel modules: nvme
0000:6a:00.0 0108: 1179:0110 (rev 01)
    DeviceName: PCIe SSD in Slot 11 Bay 2
    Subsystem: 1028:1ffb
    Kernel driver in use: nvme
    Kernel modules: nvme
```

2. Open the XML configuration of the VM to which you want to attach the PCI device.

```
# virsh edit vm-name
```

3. Add the following **<hostdev>** configuration to the **<devices>** section of the XML file. Replace the values on the **address** line with the PCI address of your device. Optionally, to change the PCI address that the device will use in the VM, you can configure a different address on the **<address type="pci">** line.

   For example, if the device address on the host is **0000:65:00.0**, and you want it to use **0000:02:00.0** in the guest, use the following configuration:

```
<hostdev mode="subsystem" type="pci" managed="yes">
  <driver name="vfio"/>
   <source>
    <address domain="0x0000" bus="0x65" slot="0x00" function="0x0"/>
   </source>
   <address type="pci" domain='0x0000' bus='0x02' slot='0x00' function='0x0'/>
</hostdev>
```

4. Optional: On IBM Z hosts, you can modify how the guest operating system will detect the PCI device. To do this, add a **<zpci>** sub-element to the **<address>** element. In the **<zpci>** line, you can adjust the **uid** and **fid** values, which modifies the PCI address and function ID of the device in the guest operating system.

```
<hostdev mode="subsystem" type="pci" managed="yes">
  <driver name="vfio"/>
   <source>
    <address domain="0x0000" bus="0x65" slot="0x00" function="0x0"/>
   </source>
   <address type="pci" domain='0x0000' bus='0x02' slot='0x00' function='0x0'>
     <zpci uid="0x0008" fid="0x001807"/>
   </address>
</hostdev>
```

   In this example:

   - **uid="0x0008"** sets the domain PCI address of the device in the VM to **0008:00:00.0**.

   - **fid="0x001807"** sets the slot value of the device to **0x001807**. As a result, the device configuration in the file system of the VM is saved to **/sys/bus/pci/slots/00001087/address**.
     If these values are not specified, **libvirt** configures them automatically.

5. Save the XML configuration.

6. If the VM is running, shut it down.

   ```
   # virsh shutdown vm-name
   ```

Verification

1. Start the VM and log in to its guest operating system.

2. In the guest operating system, confirm that the PCI device is listed.
   For example, if you configured guest device address as **0000:02:00.0**, use the following command:

   ```
   # lspci -nkD | grep 0000:02:00.0

   0000:02:00.0 8086:9a09 (rev 01)
   ```

Next steps

- Removing PCI devices from virtual machines by using the command line

Additional resources

- Attaching SR-IOV network devices to virtual machines
- Assigning a GPU to a virtual machine
- Attaching devices to virtual machines by using the web console

14.7.2. Attaching devices to virtual machines by using the web console

To add specific functionalities to your virtual machine (VM), you can use the web console to attach host devices to the VM.

NOTE

Attaching multiple host devices at the same time does not work. You can attach only one device at a time.

For more information, see RHEL 9 Known Issues.

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 .

- If you are attaching PCI devices, ensure that the status of the **managed** attribute of the **hostdev** element is set to **yes**.

NOTE

When attaching PCI devices to your VM, do not omit the **managed** attribute of the **hostdev** element, or set it to **no**. If you do so, PCI devices cannot automatically detach from the host when you pass them to the VM. They also cannot automatically reattach to the host when you turn off the VM.

As a consequence, the host may become unresponsive or shut down unexpectedly.

You can find the status of the **managed** attribute in your VM's XML configuration. The following example opens the XML configuration of the **example-VM-1** VM.

```
# virsh edit example-VM-1
```

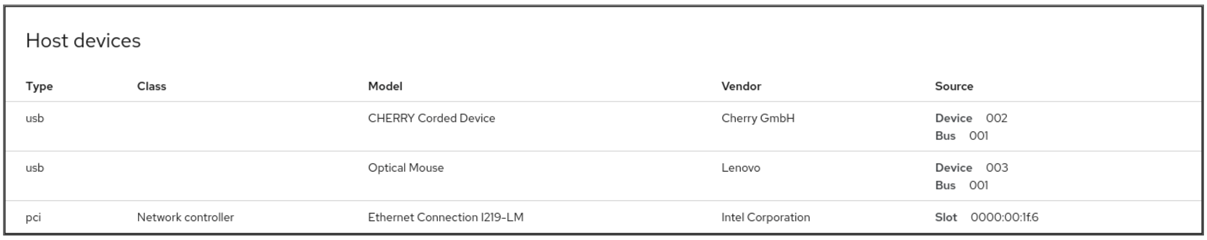
- Back up important data from the VM.
- Optional: Back up the XML configuration of your VM. For example, to back up the **example-VM-1** VM:

```
# virsh dumpxml example-VM-1 > example-VM-1.xml
```

- The web console VM plug-in is installed on your system .

Procedure

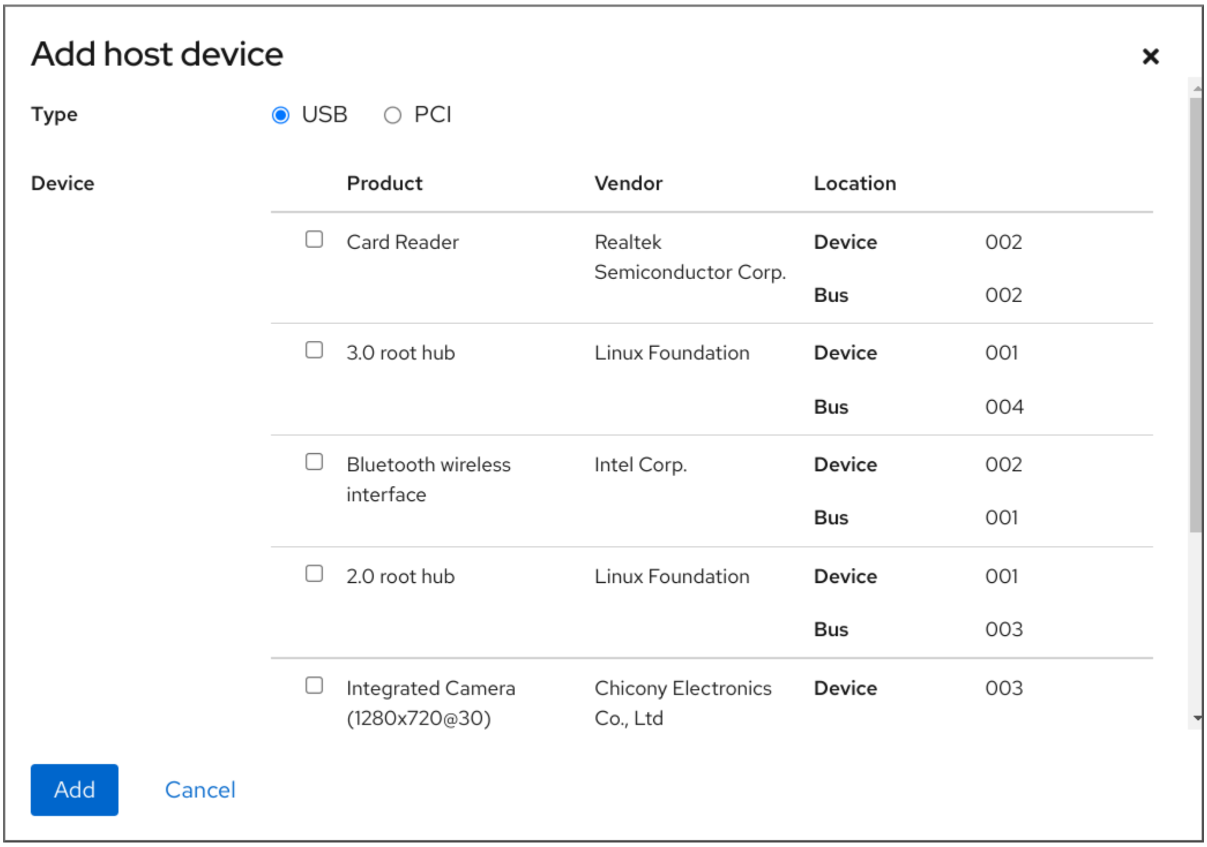
1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the VM to which you want to attach a host device.
   A new page opens with an **Overview** section with basic information about the selected VM and a **Console** section to access the VM's graphical interface.
3. Scroll to **Host devices**.
   The **Host devices** section displays information about the devices attached to the VM as well as options to **Add** or **Remove** devices.



Host devices

Type	Class	Model	Vendor	Source
usb		CHERRY Corded Device	Cherry GmbH	**Device** 002 **Bus** 001
usb		Optical Mouse	Lenovo	**Device** 003 **Bus** 001
pci	Network controller	Ethernet Connection I219-LM	Intel Corporation	**Slot** 0000:00:1f.6

4. Click **Add host device**.
   The **Add host device** dialog appears.



Add host device ×

Type ● USB ○ PCI

Device

	Product	Vendor	Location	
□	Card Reader	Realtek Semiconductor Corp.	**Device**	002
			Bus	002
□	3.0 root hub	Linux Foundation	**Device**	001
			Bus	004
□	Bluetooth wireless interface	Intel Corp.	**Device**	002
			Bus	001
□	2.0 root hub	Linux Foundation	**Device**	001
			Bus	003
□	Integrated Camera (1280x720@30)	Chicony Electronics Co., Ltd	**Device**	003

Add Cancel

5. Select the device you wish to attach to the VM.

6. Click **Add**
   The selected device is attached to the VM.

Verification

- Run the VM and check if the device appears in the **Host devices** section.

14.7.3. Removing PCI devices from virtual machines by using the command line

To remove a PCI device from a virtual machine (VM), remove the device information from the XML configuration of the VM.

Procedure

1. In the XML configuration of the VM to which the PCI device is attached, locate the **<address domain>** line in the **<hostdev>** section with the device's setting.

```
# virsh dumpxml <VM-name>

[...]
<hostdev mode='subsystem' type='pci' managed='yes'>
  <source>
    <address domain='0x0000' bus='0x65' slot='0x00' function='0x0'/>
  </source>
  <address type='pci' domain='0x0000' bus='0x02' slot='0x00' function='0x0'/>
</hostdev>
[...]
```

2. Use the **virsh detach-device** command with the the **--hostdev** option and the device address. For example, the following command persistently removes the device located in the previous step.

   ```
   # virt detach-device <VM-name> --hostdev 0000:65:00.0 --config
   Domain 'VM-name' defined successfully.
   ```

   > **NOTE**
   >
   > To remove a PCI device from a running VM, add the **--live** argument to the previous command.

3. Optional: Re-attach the PCI device to the host. For example the following command re-attaches the device removed from the VM in the previous step:

   ```
   # virsh nodedev-reattach pci_0000_65_00_0
   Device pci_0000_65_00_0 re-attached
   ```

Verification

1. Display the XML configuration of the VM again, and check that the **<hostdev>** section of the device no longer appears.

   ```
   # virsh dumpxml <VM-name>
   ```

Additional resources

- **virsh (1)** man page on your system
- Attaching devices to virtual machines

14.7.4. Removing devices from virtual machines by using the web console

To free up resources, modify the functionalities of your VM, or both, you can use the web console to modify the VM and remove host devices that are no longer required.

> **WARNING**
>
> Removing attached USB host devices by using the web console may fail because of incorrect correlation between the device and bus numbers of the USB device.
>
> For more information, see RHEL 9 Known Issues.
>
> As a workaround, remove the <hostdev> part of the USB device, from the XML configuration of VM by using the *virsh* utility. The following example opens the XML configuration of the **example-VM-1** VM:
>
> ```
> # virsh edit <example-VM-1>
> ```

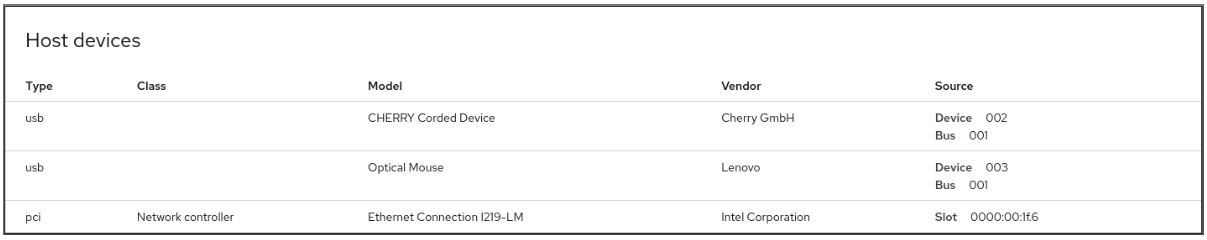
Prerequisites

- 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 web console VM plug-in is installed on your system .
- Optional: Back up the XML configuration of your VM by using **virsh dumpxml *example-VM-1*** and sending the output to a file. For example, the following backs up the configuration of your *testguest1* VM as the **testguest1.xml** file:

  ```
  # virsh dumpxml testguest1 > testguest1.xml
  # cat testguest1.xml
  <domain type='kvm' xmlns:qemu='http://libvirt.org/schemas/domain/qemu/1.0'>
    <name>testguest1</name>
    <uuid>ede29304-fe0c-4ca4-abcd-d246481acd18</uuid>
    [...]
  </domain>
  ```

Procedure

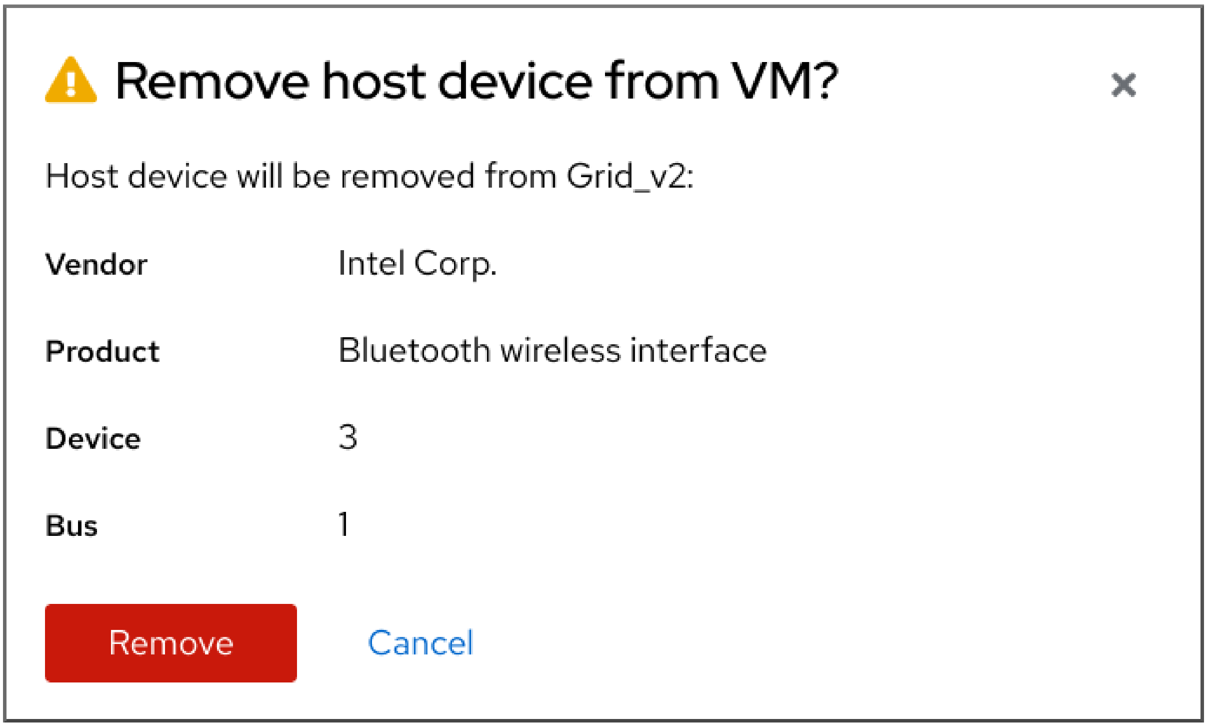
1. In the **Virtual Machines** interface, click the VM from which you want to remove a host device.
   A new page opens with an **Overview** section with basic information about the selected VM and a **Console** section to access the VM's graphical interface.
2. Scroll to **Host devices**.
   The **Host devices** section displays information about the devices attached to the VM as well as options to **Add** or **Remove** devices.



Host devices

Type	Class	Model	Vendor	Source
usb		CHERRY Corded Device	Cherry GmbH	**Device** 002 **Bus** 001
usb		Optical Mouse	Lenovo	**Device** 003 **Bus** 001
pci	Network controller	Ethernet Connection I219-LM	Intel Corporation	**Slot** 0000:00:1f.6

3. Click the **Remove** button next to the device you want to remove from the VM.
   A remove device confirmation dialog appears.



Remove host device from VM?

Host device will be removed from Grid_v2:

Vendor	Intel Corp.
Product	Bluetooth wireless interface
Device	3
Bus	1

4. Click **Remove**.
   The device is removed from the VM.

Troubleshooting

- If removing a host device causes your VM to become unbootable, use the **virsh define** utility to restore the XML configuration by reloading the XML configuration file you backed up previously.

```
# virsh define testguest1.xml
```

14.8. MANAGING SR-IOV DEVICES

An emulated virtual device often uses more CPU and memory than a hardware network device. This can limit the performance of a virtual machine (VM). However, if any devices on your virtualization host support Single Root I/O Virtualization (SR-IOV), you can use this feature to improve the device performance, and possibly also the overall performance of your VMs.

14.8.1. What is SR-IOV?

Single-root I/O virtualization (SR-IOV) is a specification that enables a single PCI Express (PCIe) device to present multiple separate PCI devices, called *virtual functions* (VFs), to the host system. Each of these devices:

- Is able to provide the same or similar service as the original PCIe device.
- Appears at a different address on the host PCI bus.
- Can be assigned to a different VM by using VFIO assignment.

For example, a single SR-IOV capable network device can present VFs to multiple VMs. While all of the VFs use the same physical card, the same network connection, and the same network cable, each of the VMs directly controls its own hardware network device, and uses no extra resources from the host.

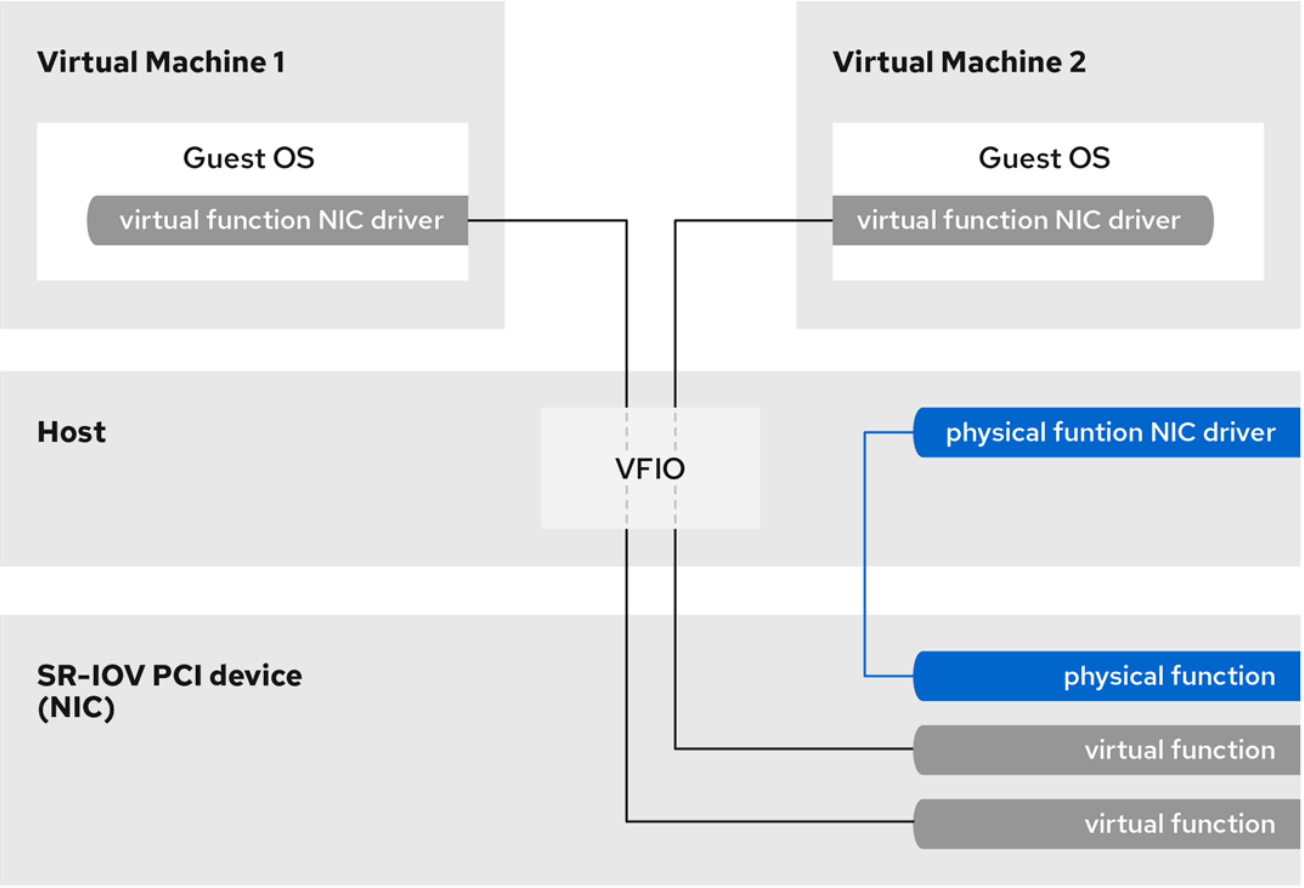
How SR-IOV works

The SR-IOV functionality is possible thanks to the introduction of the following PCIe functions:

- **Physical functions (PFs)** - A PCIe function that provides the functionality of its device (for example networking) to the host, but can also create and manage a set of VFs. Each SR-IOV capable device has one or more PFs.
- **Virtual functions (VFs)** - Lightweight PCIe functions that behave as independent devices. Each VF is derived from a PF. The maximum number of VFs a device can have depends on the device hardware. Each VF can be assigned only to a single VM at a time, but a VM can have multiple VFs assigned to it.

VMs recognize VFs as virtual devices. For example, a VF created by an SR-IOV network device appears as a network card to a VM to which it is assigned, in the same way as a physical network card appears to the host system.

Figure 14.1. SR-IOV architecture



Advantages

The primary advantages of using SR-IOV VFs rather than emulated devices are:

- Improved performance
- Reduced use of host CPU and memory resources

For example, a VF attached to a VM as a vNIC performs at almost the same level as a physical NIC, and much better than paravirtualized or emulated NICs. In particular, when multiple VFs are used simultaneously on a single host, the performance benefits can be significant.

Disadvantages

- To modify the configuration of a PF, you must first change the number of VFs exposed by the PF to zero. Therefore, you also need to remove the devices provided by these VFs from the VM to which they are assigned.
- A VM with an VFIO-assigned devices attached, including SR-IOV VFs, cannot be migrated to another host. In some cases, you can work around this limitation by pairing the assigned device with an emulated device. For example, you can bond (Red Hat Knowledgebase) an assigned networking VF to an emulated vNIC, and remove the VF before the migration.
- In addition, VFIO-assigned devices require pinning of VM memory, which increases the memory consumption of the VM and prevents the use of memory ballooning on the VM.

Additional resources

- Supported devices for SR-IOV assignment
- Configuring passthrough PCI devices on IBM Z

14.8.2. Attaching SR-IOV networking devices to virtual machines

To attach an SR-IOV networking device to a virtual machine (VM), you must create a virtual function (VF) from an SR-IOV capable network interface on the host and assign the VF as a device to a specified VM. For details, see the following instructions.

Prerequisites

- The CPU and the firmware of your host support the I/O Memory Management Unit (IOMMU).
  - If using an Intel CPU, it must support the Intel Virtualization Technology for Directed I/O (VT-d).
  - If using an AMD CPU, it must support the AMD-Vi feature.
- The host system uses Access Control Service (ACS) to provide direct memory access (DMA) isolation for PCIe topology. Verify this with the system vendor.
  For additional information, see Hardware Considerations for Implementing SR-IOV .
- The physical network device supports SR-IOV. To verify if any network devices on your system support SR-IOV, use the **lspci -v** command and look for **Single Root I/O Virtualization (SR-IOV)** in the output.

```
# lspci -v
[...]
02:00.0 Ethernet controller: Intel Corporation 82576 Gigabit Network Connection (rev 01)
```

```
 Subsystem: Intel Corporation Gigabit ET Dual Port Server Adapter
 Flags: bus master, fast devsel, latency 0, IRQ 16, NUMA node 0
 Memory at fcba0000 (32-bit, non-prefetchable) [size=128K]
[...]
 Capabilities: [150] Alternative Routing-ID Interpretation (ARI)
 Capabilities: [160] Single Root I/O Virtualization (SR-IOV)
 Kernel driver in use: igb
 Kernel modules: igb
[...]
```

- The host network interface you want to use for creating VFs is running. For example, to activate the *eth1* interface and verify it is running:

```
# ip link set eth1 up
# ip link show eth1
8: eth1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP mode
DEFAULT qlen 1000
   link/ether a0:36:9f:8f:3f:b8 brd ff:ff:ff:ff:ff:ff
   vf 0 MAC 00:00:00:00:00:00, spoof checking on, link-state auto
   vf 1 MAC 00:00:00:00:00:00, spoof checking on, link-state auto
   vf 2 MAC 00:00:00:00:00:00, spoof checking on, link-state auto
   vf 3 MAC 00:00:00:00:00:00, spoof checking on, link-state auto
```

- For SR-IOV device assignment to work, the IOMMU feature must be enabled in the host BIOS and kernel. To do so:
  - On an Intel host, enable VT-d:
    i. Regenerate the GRUB configuration with the **intel_iommu=on** and **iommu=pt** parameters:

    ```
    # grubby --args="intel_iommu=on iommu=pt" --update-kernel=ALL
    ```

    ii. Reboot the host.
  - On an AMD host, enable AMD-Vi:
    i. Regenerate the GRUB configuration with the **iommu=pt** parameter:

    ```
    # grubby --args="iommu=pt" --update-kernel=ALL
    ```

    ii. Reboot the host.
  - On an ARM 64 host, the required SMMU feature is enabled by default, but configuring the **iommu=pt** parameter is recommended as well, for better performance:
    i. Regenerate the GRUB configuration with the **iommu=pt** parameter:

    ```
    # grubby --args="iommu=pt" --update-kernel=ALL
    ```

    ii. Reboot the host.

Procedure

1. Optional: Confirm the maximum number of VFs your network device can use. To do so, use the

1. Optional: Confirm the maximum number of VFs your network device can use. To do so, use the following command and replace *eth1* with your SR-IOV compatible network device.

   ```
   # cat /sys/class/net/eth1/device/sriov_totalvfs
   7
   ```

2. Use the following command to create a virtual function (VF):

   ```
   # echo VF-number > /sys/class/net/network-interface/device/sriov_numvfs
   ```

   In the command, replace:

   - *VF-number* with the number of VFs you want to create on the PF.
   - *network-interface* with the name of the network interface for which the VFs will be created.

   The following example creates 2 VFs from the eth1 network interface:

   ```
   # echo 2 > /sys/class/net/eth1/device/sriov_numvfs
   ```

3. Verify the VFs have been added:

   ```
   # lspci | grep Ethernet
   82:00.0 Ethernet controller: Intel Corporation 82599ES 10-Gigabit SFI/SFP+ Network
   Connection (rev 01)
   82:00.1 Ethernet controller: Intel Corporation 82599ES 10-Gigabit SFI/SFP+ Network
   Connection (rev 01)
   82:10.0 Ethernet controller: Intel Corporation 82599 Ethernet Controller Virtual Function (rev
   01)
   82:10.2 Ethernet controller: Intel Corporation 82599 Ethernet Controller Virtual Function (rev
   01)
   ```

4. Make the created VFs persistent by creating a udev rule for the network interface you used to create the VFs. For example, for the *eth1* interface, create the **/etc/udev/rules.d/eth1.rules** file, and add the following line:

   ```
   ACTION=="add", SUBSYSTEM=="net", ENV{ID_NET_DRIVER}=="ixgbe",
   ATTR{device/sriov_numvfs}="2"
   ```

   This ensures that the two VFs that use the **ixgbe** driver will automatically be available for the **eth1** interface when the host starts. If you do not require persistent SR-IOV devices, skip this step.

   > **WARNING**
   >
   > Currently, the setting described above does not work correctly when attempting to make VFs persistent on Broadcom NetXtreme II BCM57810 adapters. In addition, attaching VFs based on these adapters to Windows VMs is currently not reliable.

5. Hot plug one of the newly added VF interface devices to a running VM.

```
# virsh attach-interface <vm_name> hostdev 0000:82:10.0 --mac 52:54:00:00:01:01 --
managed --live --config
```

The **--live** option attaches the device to a running VM, without persistence between boots. The **--config** option makes the configuration changes persistent. To attach the device to a shut down VM, do not use the **--live** option.

The **--mac** option specifies a MAC address for the attached interface. If you do not specify a MAC address for the interface, the VM automatically generates a permanent, pseudorandom address that begins with *52:54:00*.

IMPORTANT

If you assign an SR-IOV VF to a virtual machine by manually adding a device entry to the *<hostdev>* section of your VM's XML configuration file, the MAC address is not permanently assigned and network settings in the guest usually need to be reconfigured on every host reboot.

To avoid these complications, use the **virsh attach-interface** command as described in this step.

Verification

- If the procedure is successful, the guest operating system detects a new network interface controller.

14.8.3. Supported devices for SR-IOV assignment

Not all devices can be used for SR-IOV. The following devices have been tested and verified as compatible with SR-IOV in RHEL 9.

Networking devices

- Intel 82599ES 10 Gigabit Ethernet Controller - uses the **ixgbe** driver
- Intel Ethernet Controller XL710 Series - uses the **i40e** driver
- Intel Ethernet Network Adapter XXV710 - uses the **i40e** driver
- Intel 82576 Gigabit Ethernet Controller - uses the **igb** driver
- Broadcom NetXtreme II BCM57810 - uses the **bnx2x** driver
- Ethernet Controller E810-C for QSFP - uses the **ice** driver
- SFC9220 10/40G Ethernet Controller - uses the **sfc** driver
- FastLinQ QL41000 Series 10/25/40/50GbE Controller - uses the **qede** driver
- Mellanox MT27710 Ethernet Adapter Cards
- Mellanox MT2892 Family [ConnectX-6 Dx]

- Mellanox MT2910 [ConnextX-7]

14.9. ATTACHING DASD DEVICES TO VIRTUAL MACHINES ON IBM Z

By using the **vfio-ccw** feature, you can assign direct-access storage devices (DASDs) as mediated devices to your virtual machines (VMs) on IBM Z hosts. This for example makes it possible for the VM to access a z/OS dataset, or to provide the assigned DASDs to a z/OS machine.

Prerequisites

- You have a system with IBM Z hardware architecture supported with the FICON protocol.
- You have a target VM of a Linux operating system.
- The *driverctl* package is installed.

  ```
  # dnf install driverctl
  ```

- The necessary **vfio** kernel modules have been loaded on the host.

  ```
  # lsmod | grep vfio
  ```

  The output of this command must contain the following modules:

  - **vfio_ccw**
  - **vfio_mdev**
  - **vfio_iommu_type1**

- You have a spare DASD device for exclusive use by the VM, and you know the identifier of the device.
  The following procedure uses **0.0.002c** as an example. When performing the commands, replace **0.0.002c** with the identifier of your DASD device.

Procedure

1. Obtain the subchannel identifier of the DASD device.

   ```
   # lscss -d 0.0.002c
   Device   Subchan.  DevType CU Type Use  PIM PAM POM  CHPIDs
   ----------------------------------------------------------------------
   0.0.002c 0.0.29a8  3390/0c 3990/e9 yes  f0  f0  ff   02111221 00000000
   ```

   In this example, the subchannel identifier is detected as **0.0.29a8**. In the following commands of this procedure, replace **0.0.29a8** with the detected subchannel identifier of your device.

2. If the **lscss** command in the previous step only displayed the header output and no device information, perform the following steps:

   a. Remove the device from the **cio_ignore** list.

   ```
   # cio_ignore -r 0.0.002c
   ```

b. In the guest OS, edit the kernel command line of the VM and add the device identifier with a **!** mark to the line that starts with **cio_ignore=**, if it is not present already.

```
cio_ignore=all,!condev,!0.0.002c
```

c. Repeat step 1 on the host to obtain the subchannel identifier.

3. Bind the subchannel to the **vfio_ccw** passthrough driver.

```
# driverctl -b css set-override 0.0.29a8 vfio_ccw
```

NOTE

This binds the *0.0.29a8* subchannel to **vfio_ccw** persistently, which means the DASD will not be usable on the host. If you need to use the device on the host, you must first remove the automatic binding to 'vfio_ccw' and rebind the subchannel to the default driver:

# **driverctl -b css unset-override***0.0.29a8*

4. Define and start the DASD mediated device.

```
# cat nodedev.xml
<device>
    <parent>css_0_0_29a8</parent>
    <capability type="mdev">
        <type id="vfio_ccw-io"/>
    </capability>
</device>

# virsh nodedev-define nodedev.xml
Node device 'mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8' defined from
'nodedev.xml'

# virsh nodedev-start mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8
Device mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8 started
```

5. Shut down the VM, if it is running.

6. Display the UUID of the previously defined device and save it for the next step.

```
# virsh nodedev-dumpxml mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8

<device>
  <name>mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8</name>
  <parent>css_0_0_29a8</parent>
  <capability type='mdev'>
    <type id='vfio_ccw-io'/>
    <uuid>30820a6f-b1a5-4503-91ca-0c10ba12345a</uuid>
    <iommuGroup number='0'/>
    <attr name='assign_adapter' value='0x02'/>
    <attr name='assign_domain' value='0x002b'/>
  </capability>
</device>
```

7. Attach the mediated device to the VM. To do so, use the **virsh edit** utility to edit the XML configuration of the VM, add the following section to the XML, and replace the **uuid** value with the UUID you obtained in the previous step.

```
<hostdev mode='subsystem' type='mdev' model='vfio-ccw'>
  <source>
    <address uuid="30820a6f-b1a5-4503-91ca-0c10ba12345a"/>
  </source>
</hostdev>
```

8. Optional: Configure the mediated device to start automatically on host boot.

```
# virsh nodedev-autostart mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8
```

Verification

1. Ensure that the mediated device is configured correctly.

```
# virsh nodedev-info mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8
Name:           mdev_30820a6f_b1a5_4503_91ca_0c10ba12345a_0_0_29a8
Parent:         css_0_0_0121
Active:         yes
Persistent:     yes
Autostart:      yes
```

2. Obtain the identifier that **libvirt** assigned to the mediated DASD device. To do so, display the XML configuration of the VM and look for a **vfio-ccw** device.

```
# virsh dumpxml vm-name

<domain>
[...]
    <hostdev mode='subsystem' type='mdev' managed='no' model='vfio-ccw'>
      <source>
        <address uuid='10620d2f-ed4d-437b-8aff-beda461541f9'/>
      </source>
      <alias name='hostdev0'/>
      <address type='ccw' cssid='0xfe' ssid='0x0' devno='0x0009'/>
    </hostdev>
[...]
</domain>
```

In this example, the assigned identifier of the device is **0.0.0009**.

3. Start the VM and log in to its guest OS.

4. In the guest OS, confirm that the DASD device is listed. For example:

```
# lscss | grep 0.0.0009
0.0.0009 0.0.0007  3390/0c 3990/e9      f0  f0  ff   12212231 00000000
```

5. In the guest OS, set the device online. For example:

```
# chccwdev -e 0.0009
```

```
Setting device 0.0.0009 online
Done
```

Additional resources

- IBM documentation on **cio_ignore**
- Configuring kernel parameters at runtime

14.10. ATTACHING A WATCHDOG DEVICE TO A VIRTUAL MACHINE BY USING THE WEB CONSOLE

To force the virtual machine (VM) to perform a specified action when it stops responding, you can attach virtual watchdog devices to a VM.

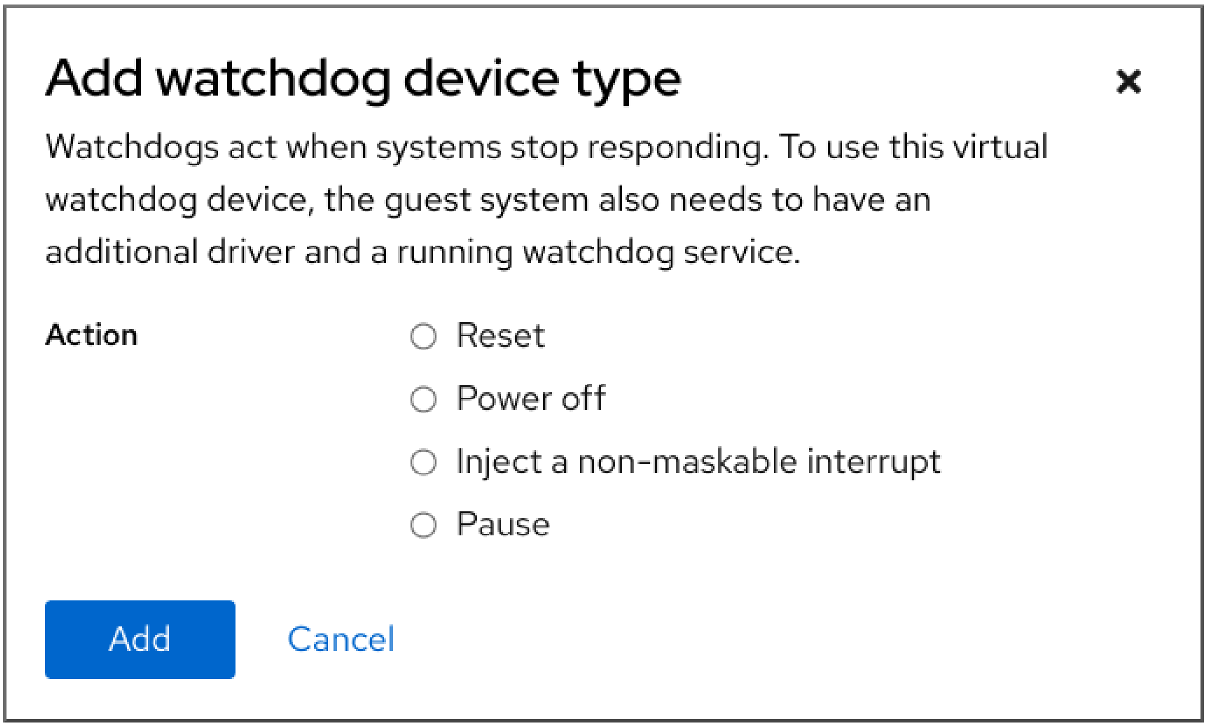
Prerequisites

- 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 web console VM plug-in on your system. For more information, see Section 8.2, "Setting up the web console to manage virtual machines" .

Procedure

1. On the command line, install the watchdog service.
   # **dnf install watchdog**
2. Shut down the VM.
3. Add the watchdog service to the VM.
   # **virt-xml *vmname* --add-device --watchdog action=reset --update**
4. Run the VM.

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface of the web console, click on the VM to which you want to add the watchdog device.
3. Click **add** next to the **Watchdog** field in the Overview pane.
   The **Add watchdog device type** dialog appears.
4. Select the action that you want the watchdog device to perform if the VM stops responding.



Add watchdog device type

Watchdogs act when systems stop responding. To use this virtual watchdog device, the guest system also needs to have an additional driver and a running watchdog service.

Action
○ Reset
○ Power off
○ Inject a non-maskable interrupt
○ Pause

5. Click **Add**.

Verification

- The action you selected is visible next to the **Watchdog** field in the Overview pane.

CHAPTER 15. MANAGING STORAGE FOR VIRTUAL MACHINES

A virtual machine (VM), just like a physical machine, requires storage for data, program, and system files. As a VM administrator, you can assign physical or network-based storage to your VMs as virtual storage. You can also modify how the storage is presented to a VM regardless of the underlying hardware.

The following sections provide information about the different types of VM storage, how they work, and how you can manage them by using the CLI or the web console.

15.1. UNDERSTANDING VIRTUAL MACHINE STORAGE

If you are new to virtual machine (VM) storage, or are unsure about how it works, the following sections provide a general overview about the various components of VM storage, how it works, management basics, and the supported solutions provided by Red Hat.

You can find information about:

- Storage pools
- Storage volumes
- Managing storage using libvirt
- Overview of VM storage
- Supported and unsupported storage pool types

15.1.1. Introduction to storage pools

A storage pool is a file, directory, or storage device, managed by **libvirt** to provide storage for virtual machines (VMs). You can divide storage pools into storage volumes, which store VM images or are attached to VMs as additional storage.

In addition, multiple VMs can share the same storage pool, allowing for better allocation of storage resources.

Storage pools can be persistent or transient:

- A persistent storage pool survives a system restart of the host machine. You can use the **virsh pool-define** to create a persistent storage pool.
- A transient storage pool only exists until the host reboots. You can use the **virsh pool-create** command to create a transient storage pool.

Storage pools can be either local or network-based (shared):

- **Local storage pools**
  Local storage pools are attached directly to the host server. They include local directories, directly attached disks, physical partitions, and Logical Volume Manager (LVM) volume groups on local devices.

  Local storage pools are useful for development, testing, and small deployments that do not require migration or have a large number of VMs.

- **Networked (shared) storage pools**

Networked storage pools include storage devices shared over a network by using standard protocols.

15.1.2. Introduction to storage volumes

Storage pools are divided into **storage volumes**. Storage volumes are abstractions of physical partitions, LVM logical volumes, file-based disk images, and other storage types handled by **libvirt**. Storage volumes are presented to VMs as local storage devices, such as disks, regardless of the underlying hardware.

On the host machine, a storage volume is referred to by its name and an identifier for the storage pool from which it derives. On the **virsh** command line, this takes the form **--pool *storage_pool volume_name***.

For example, to display information about a volume named *firstimage* in the *guest_images* pool.

```
# virsh vol-info --pool guest_images firstimage
  Name:             firstimage
  Type:             block
  Capacity:         20.00 GB
  Allocation:       20.00 GB
```

15.1.3. Storage management by using libvirt

By using the **libvirt** remote protocol, you can manage all aspects of VM storage. These operations can also be performed on a remote host. Consequently, a management application that uses **libvirt**, such as the RHEL web console, can be used to perform all the required tasks of configuring the storage of a VM.

You can use the **libvirt** API to query the list of volumes in a storage pool or to get information regarding the capacity, allocation, and available storage in that storage pool. For storage pools that support it, you can also use the **libvirt** API to create, clone, resize, and delete storage volumes. Furthermore, you can use the **libvirt** API to upload data to storage volumes, download data from storage volumes, or wipe data from storage volumes.

15.1.4. Overview of storage management

To illustrate the available options for managing storage, the following example talks about a sample NFS server that uses **mount -t nfs nfs.example.com:/path/to/share /path/to/data**.

As a storage administrator:

- You can define an NFS storage pool on the virtualization host to describe the exported server path and the client target path. Consequently, **libvirt** can mount the storage either automatically when **libvirt** is started or as needed while **libvirt** is running.

- You can simply add the storage pool and storage volume to a VM by name. You do not need to add the target path to the volume. Therefore, even if the target client path changes, it does not affect the VM.

- You can configure storage pools to autostart. When you do so, **libvirt** automatically mounts the NFS shared disk on the directory which is specified when **libvirt** is started. **libvirt** mounts the share on the specified directory, similar to the command **mount nfs.example.com:/path/to/share /vmdata**.

- You can query the storage volume paths by using the **libvirt** API. These storage volumes are basically the files present in the NFS shared disk. You can then copy these paths into the section of a VM's XML definition that describes the source storage for the VM's block devices.
- In the case of NFS, you can use an application that uses the **libvirt** API to create and delete storage volumes in the storage pool (files in the NFS share) up to the limit of the size of the pool (the storage capacity of the share).
  Note that, not all storage pool types support creating and deleting volumes.
- You can stop a storage pool when no longer required. Stopping a storage pool (**pool-destroy**) undoes the start operation, in this case, unmounting the NFS share. The data on the share is not modified by the destroy operation, despite what the name of the command suggests. For more information, see **man virsh**.

15.1.5. Supported and unsupported storage pool types

Supported storage pool types

The following is a list of storage pool types supported by RHEL:

- Directory-based storage pools
- Disk-based storage pools
- Partition-based storage pools
- iSCSI-based storage pools
- LVM-based storage pools
- NFS-based storage pools
- SCSI-based storage pools with vHBA devices
- Multipath-based storage pools
- RBD-based storage pools

Unsupported storage pool types

The following is a list of **libvirt** storage pool types not supported by RHEL:

- Sheepdog-based storage pools
- Vstorage-based storage pools
- ZFS-based storage pools
- iSCSI-direct storage pools
- GlusterFS storage pools

15.2. MANAGING VIRTUAL MACHINE STORAGE POOLS BY USING THE CLI

You can use the CLI to manage the following aspects of your storage pools to assign storage to your virtual machines (VMs):

- View storage pool information
- Create storage pools
  - Create directory-based storage pools by using the CLI
  - Create disk-based storage pools by using the CLI
  - Create filesystem-based storage pools by using the CLI
  - Create iSCSI-based storage pools by using the CLI
  - Create LVM-based storage pools by using the CLI
  - Create NFS-based storage pools by using the CLI
  - Create SCSI-based storage pools with vHBA devices by using the CLI
- Remove storage pools

15.2.1. Viewing storage pool information by using the CLI

By using the CLI, you can view a list of all storage pools with limited or full details about the storage pools. You can also filter the storage pools listed.

Procedure

- Use the **virsh pool-list** command to view storage pool information.

```
# virsh pool-list --all --details
 Name                State     Autostart  Persistent    Capacity  Allocation   Available
 default             running   yes        yes          48.97 GiB   23.93 GiB   25.03 GiB
 Downloads           running   yes        yes         175.62 GiB   62.02 GiB  113.60 GiB
 RHEL-Storage-Pool   running   yes        yes         214.62 GiB   93.02 GiB  168.60 GiB
```

Additional resources

- The **virsh pool-list --help** command

15.2.2. Creating directory-based storage pools by using the CLI

A directory-based storage pool is based on a directory in an existing mounted file system. This is useful, for example, when you want to use the remaining space on the file system for other purposes. You can use the **virsh** utility to create directory-based storage pools.

Prerequisites

- Ensure your hypervisor supports directory storage pools:

```
# virsh pool-capabilities | grep "'dir' supported='yes'"
```

  If the command displays any output, directory pools are supported.

Procedure

1. **Create a storage pool**
   Use the **virsh pool-define-as** command to define and create a directory-type storage pool. For example, to create a storage pool named **guest_images_dir** that uses the **/guest_images** directory:

   ```
   # virsh pool-define-as guest_images_dir dir --target "/guest_images"
   Pool guest_images_dir defined
   ```

   If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see Directory-based storage pool parameters .

2. **Create the storage pool target path**
   Use the **virsh pool-build** command to create a storage pool target path for a pre-formatted file system storage pool, initialize the storage source device, and define the format of the data.

   ```
   # virsh pool-build guest_images_dir
     Pool guest_images_dir built

   # ls -la /guest_images
     total 8
     drwx------.  2 root root 4096 May 31 19:38 .
     dr-xr-xr-x. 25 root root 4096 May 31 19:38 ..
   ```

3. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

   ```
   # virsh pool-list --all

     Name                 State      Autostart
     -----------------------------------------
     default              active     yes
     guest_images_dir     inactive   no
   ```

4. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

   ```
   # virsh pool-start guest_images_dir
     Pool guest_images_dir started
   ```

   NOTE

   The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

5. Optional: Turn on autostart.
   By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

```
# virsh pool-autostart guest_images_dir
  Pool guest_images_dir marked as autostarted
```

Verification

- Use the **virsh pool-info** command to verify that the storage pool is in the ***running*** state. Check if the sizes reported are as expected and if autostart is configured correctly.

```
# virsh pool-info guest_images_dir
  Name:         guest_images_dir
  UUID:         c7466869-e82a-a66c-2187-dc9d6f0877d0
  State:        running
  Persistent:   yes
  Autostart:    yes
  Capacity:     458.39 GB
  Allocation:   197.91 MB
  Available:    458.20 GB
```

15.2.3. Creating disk-based storage pools by using the CLI

In a disk-based storage pool, the pool is based on a disk partition. This is useful, for example, when you want to have an entire disk partition dedicated as virtual machine (VM) storage. You can use the **virsh** utility to create disk-based storage pools.

Prerequisites

- Ensure your hypervisor supports disk-based storage pools:

  ```
  # virsh pool-capabilities | grep "'disk' supported='yes'"
  ```

  If the command displays any output, disk-based pools are supported.

- Prepare a device on which you will base the storage pool. For this purpose, prefer partitions (for example, **/dev/sdb1**) or LVM volumes. If you provide a VM with write access to an entire disk or block device (for example, **/dev/sdb**), the VM will likely partition it or create its own LVM groups on it. This can result in system errors on the host.
  However, if you require using an entire block device for the storage pool, Red Hat recommends protecting any important partitions on the device from GRUB’s **os-prober** function. To do so, edit the **/etc/default/grub** file and apply one of the following configurations:

  - Disable **os-prober**.

    ```
    GRUB_DISABLE_OS_PROBER=true
    ```

  - Prevent **os-prober** from discovering a specific partition. For example:

    ```
    GRUB_OS_PROBER_SKIP_LIST="5ef6313a-257c-4d43@/dev/sdb1"
    ```

- Back up any data on the selected storage device before creating a storage pool. Depending on the version of **libvirt** being used, dedicating a disk to a storage pool may reformat and erase all data currently stored on the disk device.

Procedure

1. **Create a storage pool**
   Use the **virsh pool-define-as** command to define and create a disk-type storage pool. The following example creates a storage pool named **guest_images_disk** that uses the **/dev/sdb** device and is mounted on the /dev directory.

   ```
   # virsh pool-define-as guest_images_disk disk --source-format=gpt --source-dev=/dev/sdb --
   target /dev
   Pool guest_images_disk defined
   ```

   If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see Disk-based storage pool parameters .

2. **Create the storage pool target path**
   Use the **virsh pool-build** command to create a storage pool target path for a pre-formatted file-system storage pool, initialize the storage source device, and define the format of the data.

   ```
   # virsh pool-build guest_images_disk
     Pool guest_images_disk built
   ```

   NOTE

   Building the target path is only necessary for disk-based, file system-based, and logical storage pools. If **libvirt** detects that the source storage device's data format differs from the selected storage pool type, the build fails, unless the ***overwrite*** option is specified.

3. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

   ```
   # virsh pool-list --all

     Name                 State      Autostart
     -----------------------------------------
     default              active     yes
     guest_images_disk    inactive   no
   ```

4. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

   ```
   # virsh pool-start guest_images_disk
     Pool guest_images_disk started
   ```

   NOTE

   The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

5. Optional: Turn on autostart.

   By default, a storage pool defined with the **virsh** command is not set to automatically start each

By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

```
# virsh pool-autostart guest_images_disk
  Pool guest_images_disk marked as autostarted
```

Verification

- Use the **virsh pool-info** command to verify that the storage pool is in the ***running*** state. Check if the sizes reported are as expected and if autostart is configured correctly.

```
# virsh pool-info guest_images_disk
  Name:          guest_images_disk
  UUID:         c7466869-e82a-a66c-2187-dc9d6f0877d0
  State:        running
  Persistent:    yes
  Autostart:     yes
  Capacity:      458.39 GB
  Allocation:    197.91 MB
  Available:     458.20 GB
```

15.2.4. Creating filesystem-based storage pools by using the CLI

When you want to create a storage pool on a file system that is not mounted, use the filesystem-based storage pool. This storage pool is based on a given file-system mountpoint. You can use the **virsh** utility to create filesystem-based storage pools.

Prerequisites

- Ensure your hypervisor supports filesystem-based storage pools:

```
# virsh pool-capabilities | grep "'fs' supported='yes'"
```

  If the command displays any output, file-based pools are supported.

- Prepare a device on which you will base the storage pool. For this purpose, prefer partitions (for example, **/dev/sdb1**) or LVM volumes. If you provide a VM with write access to an entire disk or block device (for example, **/dev/sdb**), the VM will likely partition it or create its own LVM groups on it. This can result in system errors on the host.
  However, if you require using an entire block device for the storage pool, Red Hat recommends protecting any important partitions on the device from GRUB's **os-prober** function. To do so, edit the **/etc/default/grub** file and apply one of the following configurations:

  - Disable **os-prober**.

```
GRUB_DISABLE_OS_PROBER=true
```

  - Prevent **os-prober** from discovering a specific partition. For example:

```
GRUB_OS_PROBER_SKIP_LIST="5ef6313a-257c-4d43@/dev/sdb1"
```

Procedure

1. **Create a storage pool**
   Use the **virsh pool-define-as** command to define and create a filesystem-type storage pool. For example, to create a storage pool named **guest_images_fs** that uses the **/dev/sdc1** partition, and is mounted on the /guest_images directory:

   ```
   # virsh pool-define-as guest_images_fs fs --source-dev /dev/sdc1 --target /guest_images
   Pool guest_images_fs defined
   ```

   If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see Filesystem-based storage pool parameters .

2. **Define the storage pool target path**
   Use the **virsh pool-build** command to create a storage pool target path for a pre-formatted file-system storage pool, initialize the storage source device, and define the format of the data.

   ```
   # virsh pool-build guest_images_fs
     Pool guest_images_fs built

   # ls -la /guest_images
     total 8
     drwx------.  2 root root 4096 May 31 19:38 .
     dr-xr-xr-x. 25 root root 4096 May 31 19:38 ..
   ```

3. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

   ```
   # virsh pool-list --all

     Name                 State      Autostart
     -------------------------------------------
     default              active     yes
     guest_images_fs      inactive   no
   ```

4. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

   ```
   # virsh pool-start guest_images_fs
     Pool guest_images_fs started
   ```

   NOTE

   The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

5. Optional: Turn on autostart
   By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

```
# virsh pool-autostart guest_images_fs
  Pool guest_images_fs marked as autostarted
```

Verification

1. Use the **virsh pool-info** command to verify that the storage pool is in the ***running*** state. Check if the sizes reported are as expected and if autostart is configured correctly.

```
# virsh pool-info guest_images_fs
  Name:           guest_images_fs
  UUID:           c7466869-e82a-a66c-2187-dc9d6f0877d0
  State:          running
  Persistent:     yes
  Autostart:      yes
  Capacity:       458.39 GB
  Allocation:     197.91 MB
  Available:      458.20 GB
```

2. Verify there is a **lost+found** directory in the target path on the file system, indicating that the device is mounted.

```
# mount | grep /guest_images
  /dev/sdc1 on /guest_images type ext4 (rw)

# ls -la /guest_images
  total 24
  drwxr-xr-x.  3 root root  4096 May 31 19:47 .
  dr-xr-xr-x. 25 root root  4096 May 31 19:38 ..
  drwx------.  2 root root 16384 May 31 14:18 lost+found
```

15.2.5. Creating iSCSI-based storage pools by using the CLI

Internet Small Computer Systems Interface (iSCSI) is an IP-based storage networking standard for linking data storage facilities. If you want to have a storage pool on an iSCSI server, you can use the **virsh** utility to create iSCSI-based storage pools.

Prerequisites

- Ensure your hypervisor supports iSCSI-based storage pools:

```
# virsh pool-capabilities | grep "'iscsi' supported='yes'"
```

If the command displays any output, iSCSI-based pools are supported.

Procedure

1. **Create a storage pool**
Use the **virsh pool-define-as** command to define and create an iSCSI-type storage pool. For example, to create a storage pool named **guest_images_iscsi** that uses the **iqn.2010-05.com.example.server1:iscsirhel7guest** IQN on the **server1.example.com**, and is mounted on the **/dev/disk/by-path** path:

```
# virsh pool-define-as --name guest_images_iscsi --type iscsi --source-host
```

```
server1.example.com --source-dev iqn.2010-05.com.example.server1:iscsirhel7guest --
target /dev/disk/by-path
Pool guest_images_iscsi defined
```

If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see iSCSI-based storage pool parameters .

2. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

```
# virsh pool-list --all

  Name                 State      Autostart
  -----------------------------------------
  default              active     yes
  guest_images_iscsi   inactive   no
```

3. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

```
# virsh pool-start guest_images_iscsi
  Pool guest_images_iscsi started
```

> **NOTE**
>
> The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

4. Optional: Turn on autostart.
   By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

```
# virsh pool-autostart guest_images_iscsi
  Pool guest_images_iscsi marked as autostarted
```

Verification

- Use the **virsh pool-info** command to verify that the storage pool is in the ***running*** state. Check if the sizes reported are as expected and if autostart is configured correctly.

```
# virsh pool-info guest_images_iscsi
  Name:           guest_images_iscsi
  UUID:          c7466869-e82a-a66c-2187-dc9d6f0877d0
  State:         running
  Persistent:     yes
  Autostart:      yes
  Capacity:       458.39 GB
  Allocation:     197.91 MB
  Available:      458.20 GB
```

15.2.6. Creating LVM-based storage pools by using the CLI

If you want to have a storage pool that is part of an LVM volume group, you can use the **virsh** utility to create LVM-based storage pools.

Recommendations

Be aware of the following before creating an LVM-based storage pool:

- LVM-based storage pools do not provide the full flexibility of LVM.
- **libvirt** supports thin logical volumes, but does not provide the features of thin storage pools.
- LVM-based storage pools are volume groups. You can create volume groups by using the **virsh** utility, but this way you can only have one device in the created volume group. To create a volume group with multiple devices, use the LVM utility instead, see How to create a volume group in Linux with LVM.
  For more detailed information about volume groups, refer to Configuring and managing logical volumes.
- LVM-based storage pools require a full disk partition. If you activate a new partition or device by using **virsh** commands, the partition will be formatted and all data will be erased. If you are using a host's existing volume group, as in these procedures, nothing will be erased.

Prerequisites

- Ensure your hypervisor supports LVM-based storage pools:

  ```
  # virsh pool-capabilities | grep "'logical' supported='yes'"
  ```

  If the command displays any output, LVM-based pools are supported.

Procedure

1. **Create a storage pool**
   Use the **virsh pool-define-as** command to define and create an LVM-type storage pool. For example, the following command creates a storage pool named **guest_images_lvm** that uses the **lvm_vg** volume group and is mounted on the **/dev/lvm_vg** directory:

   ```
   # virsh pool-define-as guest_images_lvm logical --source-name lvm_vg --target /dev/lvm_vg
   Pool guest_images_lvm defined
   ```

   If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see LVM-based storage pool parameters.

2. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

   ```
   # virsh pool-list --all

     Name                   State      Autostart
     -------------------------------------------
     default                active     yes
     guest_images_lvm       inactive   no
   ```

3. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

   ```
   # virsh pool-start guest_images_lvm
     Pool guest_images_lvm started
   ```

   NOTE

   The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

4. Optional: Turn on autostart.
   By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

   ```
   # virsh pool-autostart guest_images_lvm
     Pool guest_images_lvm marked as autostarted
   ```

Verification

- Use the **virsh pool-info** command to verify that the storage pool is in the ***running*** state. Check if the sizes reported are as expected and if autostart is configured correctly.

  ```
  # virsh pool-info guest_images_lvm
    Name:          guest_images_lvm
    UUID:          c7466869-e82a-a66c-2187-dc9d6f0877d0
    State:         running
    Persistent:    yes
    Autostart:     yes
    Capacity:      458.39 GB
    Allocation:    197.91 MB
    Available:     458.20 GB
  ```

15.2.7. Creating NFS-based storage pools by using the CLI

If you want to have a storage pool on a Network File System (NFS) server, you can use the **virsh** utility to create NFS-based storage pools.

Prerequisites

- Ensure your hypervisor supports NFS-based storage pools:

  ```
  # virsh pool-capabilities | grep "<value>nfs</value>"
  ```

  If the command displays any output, NFS-based pools are supported.

Procedure

1. **Create a storage pool**
   Use the virsh **pool-define-as** command to define and create an NFS-type storage pool. For example, to create a storage pool named **guest_images_netfs** that uses a NFS server with IP

111.222.111.222 mounted on the server directory **/home/net_mount** by using the target directory **/var/lib/libvirt/images/nfspool**:

```
# virsh pool-define-as --name guest_images_netfs --type netfs --source-
host='111.222.111.222' --source-path='/home/net_mount' --source-format='nfs' --
target='/var/lib/libvirt/images/nfspool'
```

If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see NFS-based storage pool parameters .

2. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

```
# virsh pool-list --all

 Name                 State      Autostart
 -----------------------------------------
 default              active     yes
 guest_images_netfs   inactive   no
```

3. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

```
# virsh pool-start guest_images_netfs
 Pool guest_images_netfs started
```

NOTE

The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

4. Optional: Turn on autostart.
   By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

```
# virsh pool-autostart guest_images_netfs
 Pool guest_images_netfs marked as autostarted
```

Verification

- Use the **virsh pool-info** command to verify that the storage pool is in the ***running*** state. Check if the sizes reported are as expected and if autostart is configured correctly.

```
# virsh pool-info guest_images_netfs
 Name:           guest_images_netfs
 UUID:          c7466869-e82a-a66c-2187-dc9d6f0877d0
 State:         running
 Persistent:     yes
 Autostart:      yes
 Capacity:      458.39 GB
 Allocation:    197.91 MB
 Available:     458.20 GB
```

15.2.8. Creating SCSI-based storage pools with vHBA devices by using the CLI

If you want to have a storage pool on a Small Computer System Interface (SCSI) device, your host must be able to connect to the SCSI device by using a virtual host bus adapter (vHBA). You can then use the **virsh** utility to create SCSI-based storage pools.

Prerequisites

- Ensure your hypervisor supports SCSI-based storage pools:

  ```
  # virsh pool-capabilities | grep "'scsi' supported='yes'"
  ```

  If the command displays any output, SCSI-based pools are supported.

- Before creating a SCSI-based storage pools with vHBA devices, create a vHBA. For more information, see Creating vHBAs.

Procedure

1. **Create a storage pool**
   Use the **virsh pool-define-as** command to define and create SCSI storage pool by using a vHBA. For example, the following creates a storage pool named **guest_images_vhba** that uses a vHBA identified by the **scsi_host3** parent adapter, world-wide port number **5001a4ace3ee047d**, and world-wide node number **5001a4a93526d0a1**. The storage pool is mounted on the **/dev/disk/** directory:

   ```
   # virsh pool-define-as guest_images_vhba scsi --adapter-parent scsi_host3 --adapter-wwnn
   5001a4a93526d0a1 --adapter-wwpn 5001a4ace3ee047d --target /dev/disk/
   Pool guest_images_vhba defined
   ```

   If you already have an XML configuration of the storage pool you want to create, you can also define the pool based on the XML. For details, see Parameters for SCSI-based storage pools with vHBA devices.

2. **Verify that the pool was created**
   Use the **virsh pool-list** command to verify that the pool was created.

   ```
   # virsh pool-list --all

    Name                 State      Autostart
    -----------------------------------------
    default              active     yes
    guest_images_vhba    inactive   no
   ```

3. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

   ```
   # virsh pool-start guest_images_vhba
    Pool guest_images_vhba started
   ```

NOTE

The **virsh pool-start** command is only necessary for persistent storage pools. Transient storage pools are automatically started when they are created.

4. Optional: Turn on autostart.
   By default, a storage pool defined with the **virsh** command is not set to automatically start each time virtualization services start. Use the **virsh pool-autostart** command to configure the storage pool to autostart.

```
# virsh pool-autostart guest_images_vhba
  Pool guest_images_vhba marked as autostarted
```

Verification

- Use the **virsh pool-info** command to verify that the storage pool is in the *running* state. Check if the sizes reported are as expected and if autostart is configured correctly.

```
# virsh pool-info guest_images_vhba
  Name:           guest_images_vhba
  UUID:          c7466869-e82a-a66c-2187-dc9d6f0877d0
  State:         running
  Persistent:     yes
  Autostart:      yes
  Capacity:       458.39 GB
  Allocation:     197.91 MB
  Available:      458.20 GB
```

15.2.9. Deleting storage pools by using the CLI

To remove a storage pool from your host system, you must stop the pool and remove its XML definition.

Procedure

1. List the defined storage pools by using the **virsh pool-list** command.

```
# virsh pool-list --all
Name                 State      Autostart
-------------------------------------------
default              active     yes
Downloads            active     yes
RHEL-Storage-Pool   active     yes
```

2. Stop the storage pool you want to delete by using the **virsh pool-destroy** command.

```
# virsh pool-destroy Downloads
Pool Downloads destroyed
```

3. Optional: For some types of storage pools, you can remove the directory where the storage pool resides by using the **virsh pool-delete** command. Note that to do so, the directory must be empty.

```
# virsh pool-delete Downloads
Pool Downloads deleted
```

4. Delete the definition of the storage pool by using the **virsh pool-undefine** command.

```
# virsh pool-undefine Downloads
Pool Downloads has been undefined
```

Verification

- Confirm that the storage pool was deleted.

```
# virsh pool-list --all
Name                 State      Autostart
-------------------------------------------
default              active     yes
rhel-Storage-Pool    active     yes
```

15.3. MANAGING VIRTUAL MACHINE STORAGE POOLS BY USING THE WEB CONSOLE

By using the RHEL web console, you can manage the storage pools to assign storage to your virtual machines (VMs).

You can use the web console to:

- View storage pool information.
- Create storage pools:
  - Create directory-based storage pools.
  - Create NFS-based storage pools.
  - Create iSCSI-based storage pools.
  - Create LVM-based storage pools.
- Remove storage pools.
- Deactivate storage pools.

15.3.1. Viewing storage pool information by using the web console

By using the web console, you can view detailed information about storage pools available on your system. Storage pools can be used to create disk images for your virtual machines.

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.

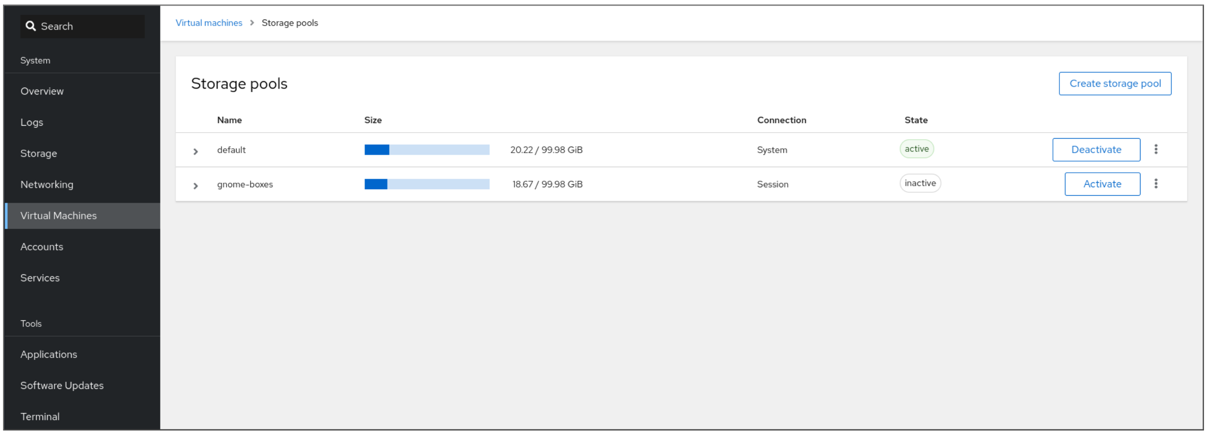
For instructions, see Installing and enabling the web console .

- The web console VM plug-in 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. Click **Storage Pools** at the top of the **Virtual Machines** interface.
   The **Storage pools** window appears, showing a list of configured storage pools.



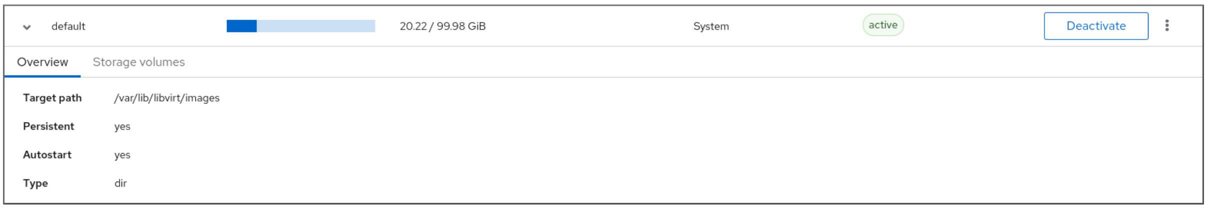
Storage pools

Name	Size		Connection	State	
› default		20.22 / 99.98 GiB	System	active	Deactivate ⋮
› gnome-boxes		18.67 / 99.98 GiB	Session	inactive	Activate ⋮

The information includes the following:

- **Name** - The name of the storage pool.
- **Size** - The current allocation and the total capacity of the storage pool.
- **Connection** - The connection used to access the storage pool.
- **State** - The state of the storage pool.

3. Click the arrow next to the storage pool whose information you want to see.
   The row expands to reveal the Overview pane with detailed information about the selected storage pool.



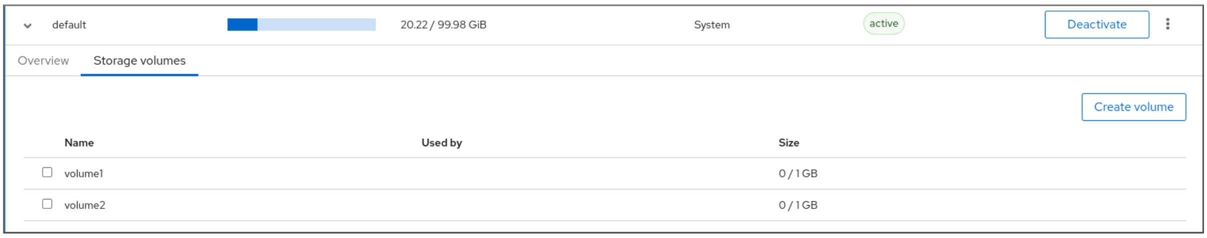
⌄ default 20.22 / 99.98 GiB System active

Target path	/var/lib/libvirt/images
Persistent	yes
Autostart	yes
Type	dir

The information includes:

- **Target path** - The location of the storage pool.
- **Persistent** - Indicates whether or not the storage pool has a persistent configuration.
- **Autostart** - Indicates whether or not the storage pool starts automatically when the system boots up.
- **Type** - The type of the storage pool.

4. To view a list of storage volumes associated with the storage pool, click **Storage Volumes**.
   The Storage Volumes pane appears, showing a list of configured storage volumes.



	Name	Used by	Size
□	volume1		0 / 1 GB
□	volume2		0 / 1 GB

The information includes:

- **Name** - The name of the storage volume.
- **Used by** - The VM that is currently using the storage volume.
- **Size** - The size of the volume.

Additional resources

- Viewing virtual machine information by using the web console

15.3.2. Creating directory-based storage pools by using the web console

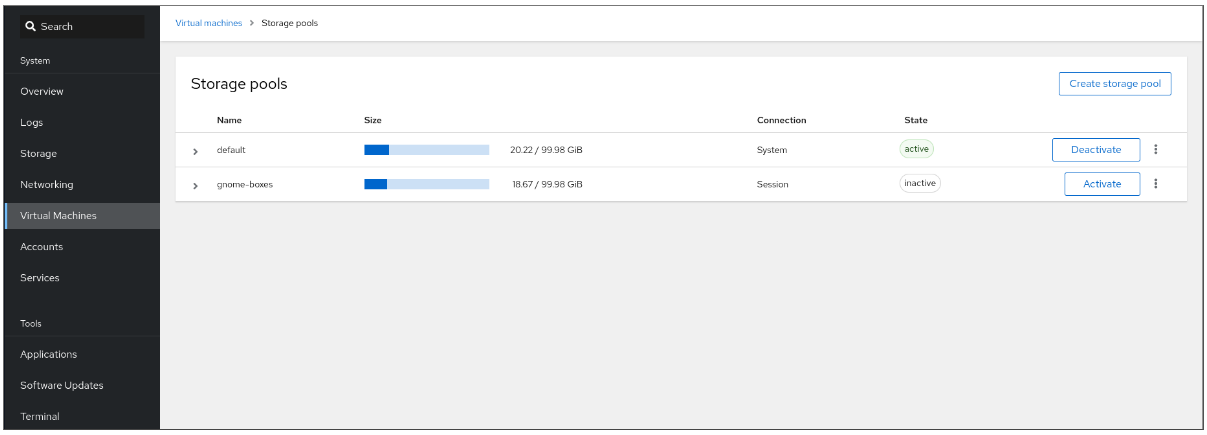
A directory-based storage pool is based on a directory in an existing mounted file system. This is useful, for example, when you want to use the remaining space on the file system for other purposes.

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 web console VM plug-in 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 RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.



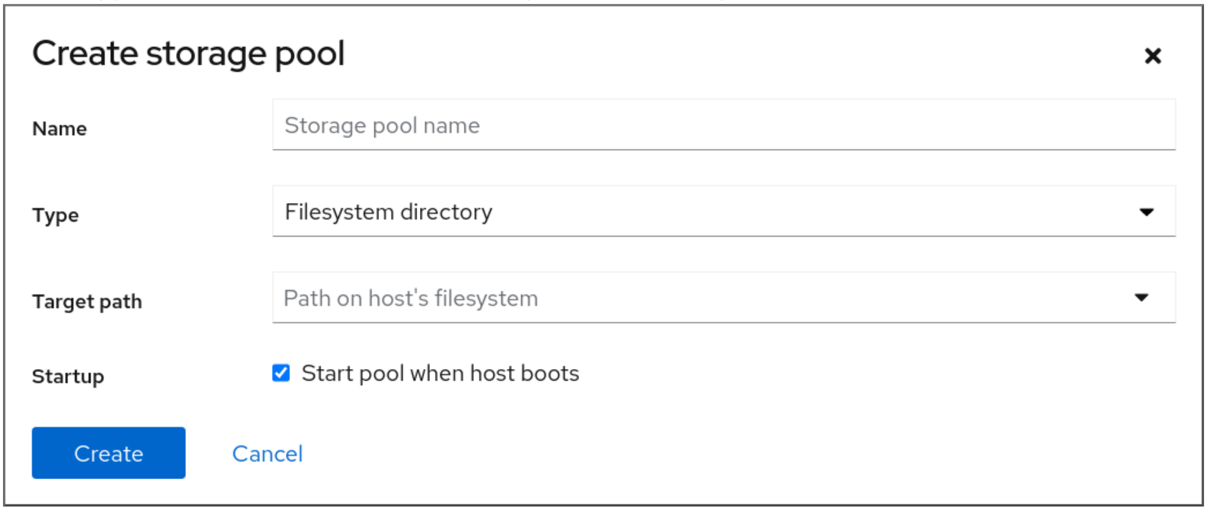
Storage pools

Name	Size	Connection	State	
default	20.22 / 99.98 GiB	System	active	Deactivate
gnome-boxes	18.67 / 99.98 GiB	Session	inactive	Activate

3. Click **Create storage pool**.
   The **Create storage pool** dialog appears.

4. Enter a name for the storage pool.

5. In the **Type** drop down menu, select **Filesystem directory**.



Create storage pool

Name: Storage pool name

Type: Filesystem directory

Target path: Path on host's filesystem

Startup: ☑ Start pool when host boots

NOTE

If you do not see the **Filesystem directory** option in the drop down menu, then your hypervisor does not support directory-based storage pools.

6. Enter the following information:
   - **Target path** - The location of the storage pool.
   - **Startup** - Whether or not the storage pool starts when the host boots.

7. Click **Create**.
   The storage pool is created, the **Create Storage Pool**dialog closes, and the new storage pool appears in the list of storage pools.

Additional resources

- Understanding storage pools
- Viewing storage pool information by using the web console

15.3.3. Creating NFS-based storage pools by using the web console

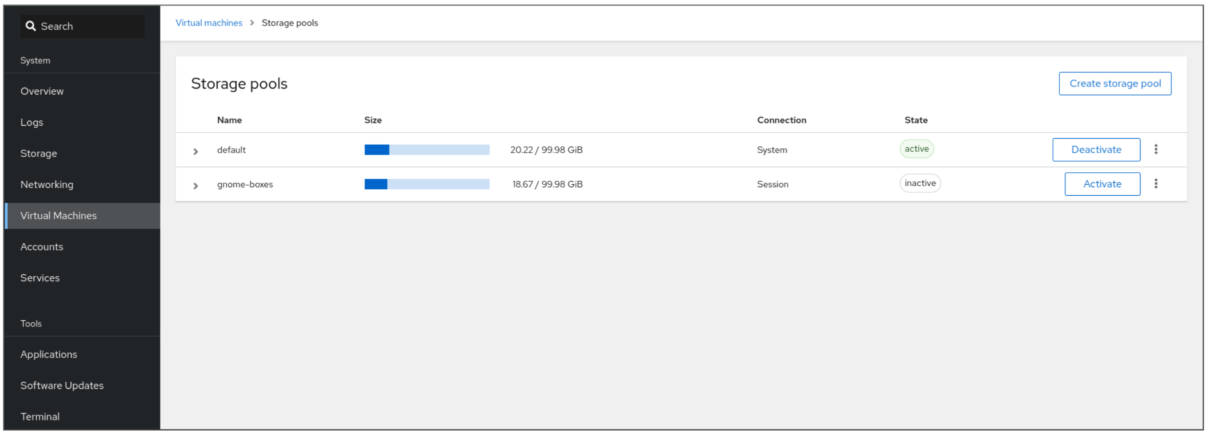
An NFS-based storage pool is based on a file system that is hosted on a server.

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 web console VM plug-in is installed on your system.

Procedure

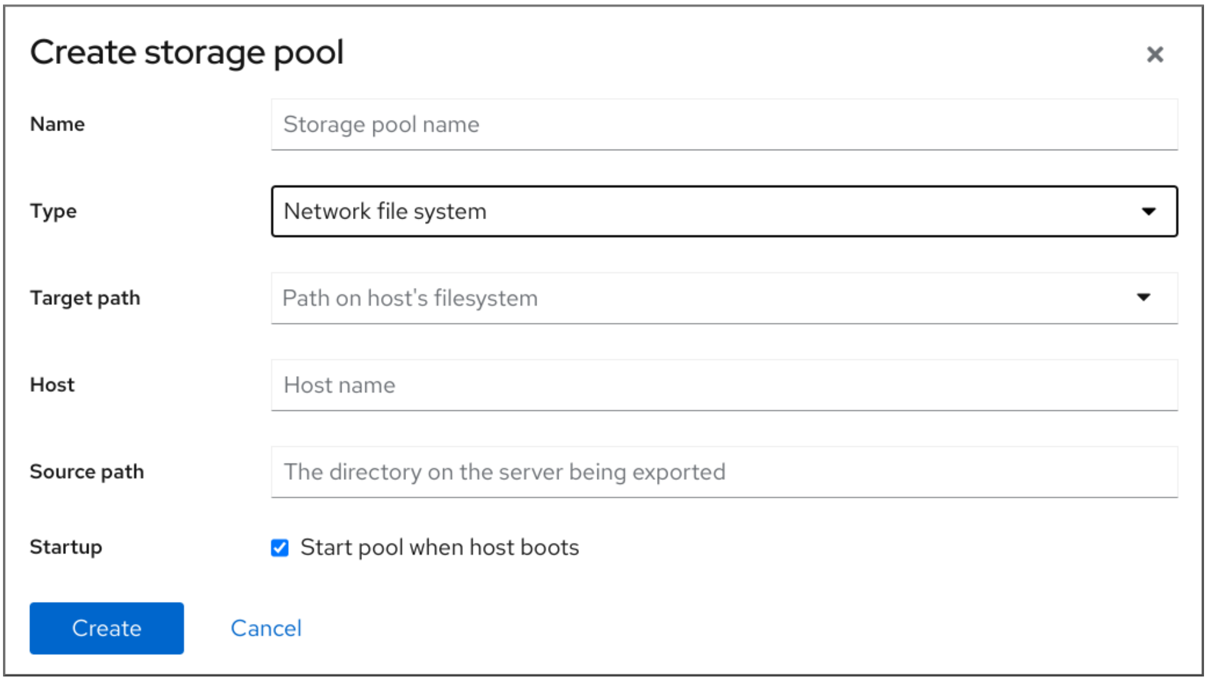
1. Log in to the RHEL 9 web console. For details, see Logging in to the web console .
2. In the RHEL web console, click **Storage pools** in the **Virtual Machines** tab. The **Storage pools** window appears, showing a list of configured storage pools, if any.



Storage pools

Name	Size	Connection	State
default	20.22 / 99.98 GiB	System	active
gnome-boxes	18.67 / 99.98 GiB	Session	inactive

3. Click **Create storage pool**. The **Create storage pool** dialog appears.
4. Enter a name for the storage pool.
5. In the **Type** drop down menu, select **Network file system**.



Create storage pool

Name: Storage pool name

Type: Network file system

Target path: Path on host's filesystem

Host: Host name

Source path: The directory on the server being exported

Startup: ☑ Start pool when host boots

NOTE

If you do not see the **Network file system** option in the drop down menu, then your hypervisor does not support nfs-based storage pools.

6. Enter the rest of the information:
   - **Target path** - The path specifying the target. This will be the path used for the storage pool.
   - **Host** - The hostname of the network server where the mount point is located. This can be a hostname or an IP address.
   - **Source path** - The directory used on the network server.
   - **Startup** - Whether or not the storage pool starts when the host boots.
7. Click **Create**.
   The storage pool is created. The **Create storage pool** dialog closes, and the new storage pool appears in the list of storage pools.

Additional resources

- Understanding storage pools
- Viewing storage pool information by using the web console

15.3.4. Creating iSCSI-based storage pools by using the web console

An iSCSI-based storage pool is based on the Internet Small Computer Systems Interface (iSCSI), an IP-based storage networking standard for linking data storage facilities.

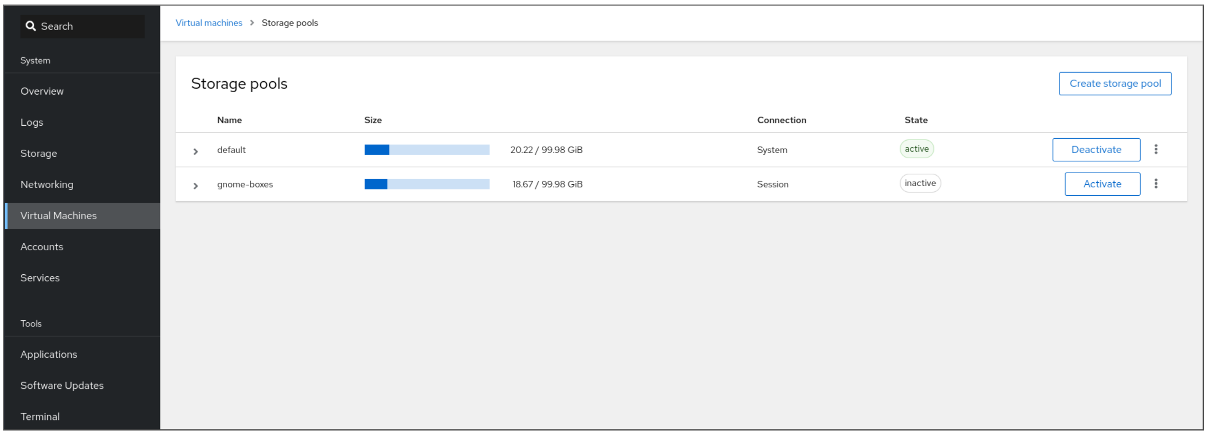
Prerequisites

- 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 web console VM plug-in is installed on your system.

Procedure

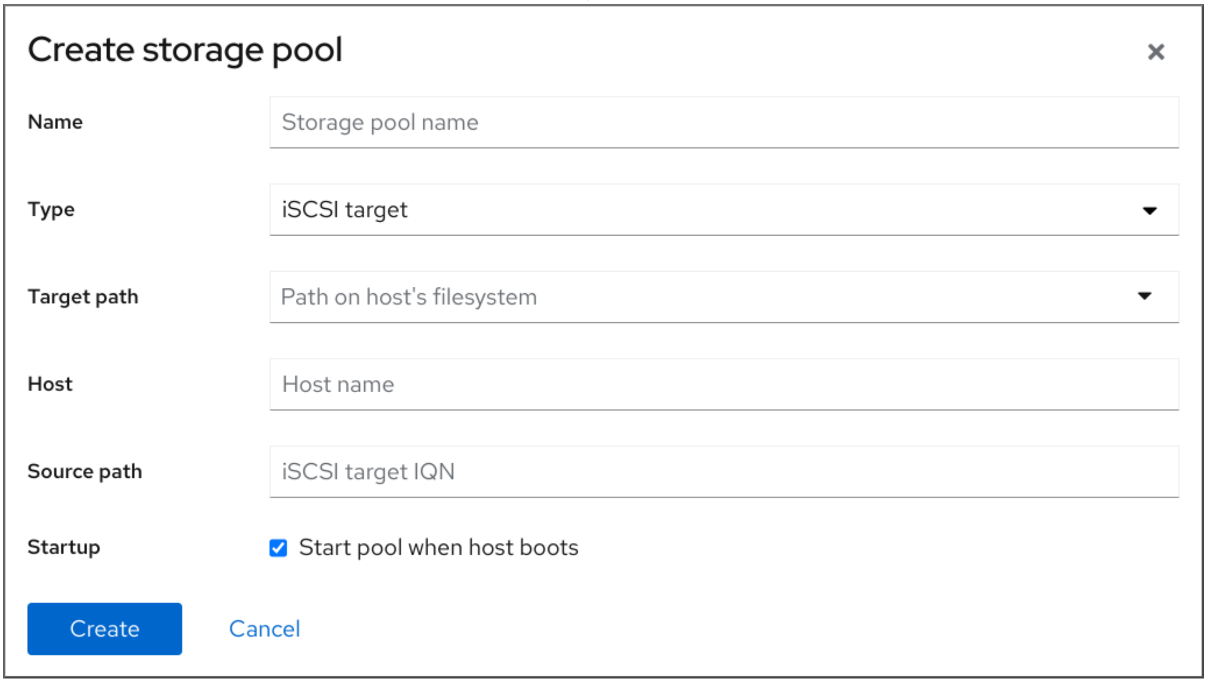
1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.



Storage pools

	Name	Size	Connection	State	
›	default	20.22 / 99.98 GiB	System	active	Deactivate ⋮
›	gnome-boxes	18.67 / 99.98 GiB	Session	inactive	Activate ⋮

3. Click **Create storage pool**.
   The **Create storage pool** dialog appears.
4. Enter a name for the storage pool.
5. In the **Type** drop down menu, select **iSCSI target**.



Create storage pool ×

Name	Storage pool name
Type	iSCSI target ▾
Target path	Path on host's filesystem ▾
Host	Host name
Source path	iSCSI target IQN
Startup	☑ Start pool when host boots

6. Enter the rest of the information:

- **Target Path** - The path specifying the target. This will be the path used for the storage pool.
- **Host** - The hostname or IP address of the ISCSI server.
- **Source path** - The unique iSCSI Qualified Name (IQN) of the iSCSI target.
- **Startup** - Whether or not the storage pool starts when the host boots.

7. Click **Create**.
   The storage pool is created. The **Create storage pool** dialog closes, and the new storage pool appears in the list of storage pools.

Additional resources

- Understanding storage pools
- Viewing storage pool information by using the web console

15.3.5. Creating disk-based storage pools by using the web console

A disk-based storage pool uses entire disk partitions.

> **WARNING**
>
> - Depending on the version of libvirt being used, dedicating a disk to a storage pool may reformat and erase all data currently stored on the disk device. It is strongly recommended that you back up the data on the storage device before creating a storage pool.
> - When whole disks or block devices are passed to the VM, the VM will likely partition it or create its own LVM groups on it. This can cause the host machine to detect these partitions or LVM groups and cause errors. These errors can also occur when you manually create partitions or LVM groups and pass them to the VM.
>
>   To avoid theses errors, use file-based storage pools instead.

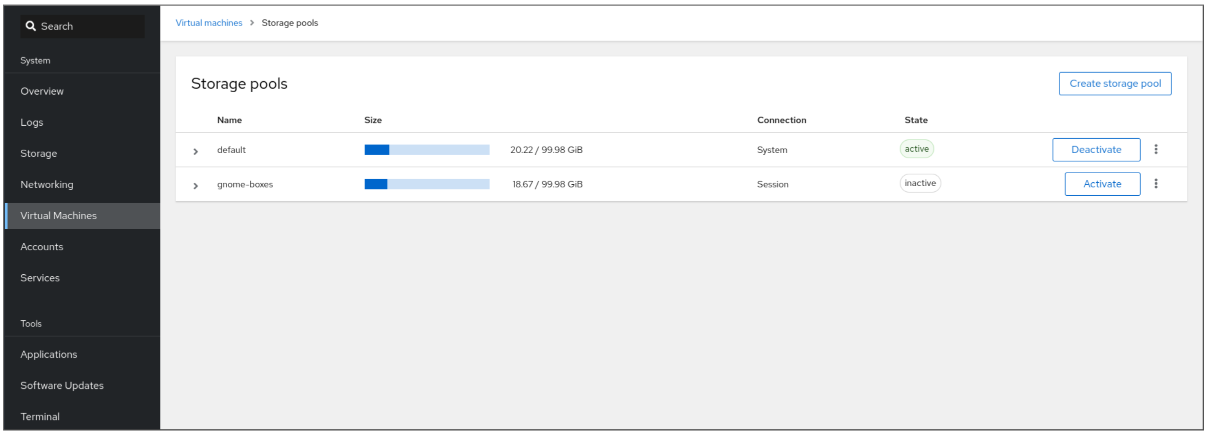
Prerequisites

- 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 web console VM plug-in 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 RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.



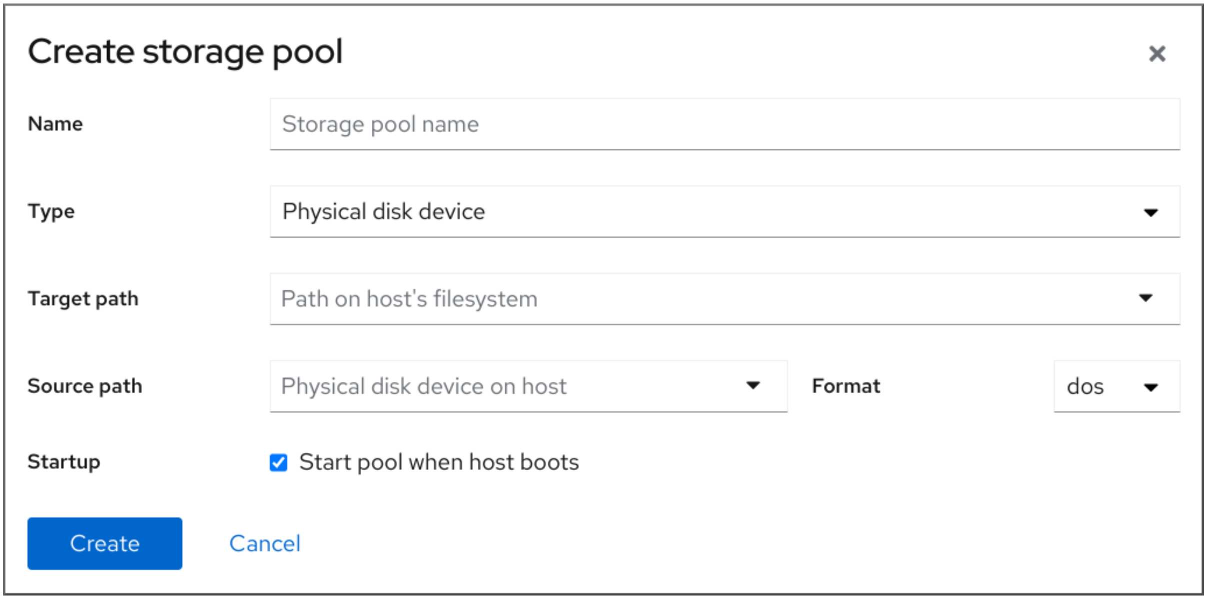
Storage pools

	Name	Size		Connection	State		
›	default		20.22 / 99.98 GiB	System	active	Deactivate	⋮
›	gnome-boxes		18.67 / 99.98 GiB	Session	inactive	Activate	⋮

3. Click **Create storage pool**.
   The **Create storage pool** dialog appears.

4. Enter a name for the storage pool.

5. In the **Type** drop down menu, select **Physical disk device**.



Create storage pool

Name	Storage pool name		
Type	Physical disk device		
Target path	Path on host's filesystem		
Source path	Physical disk device on host	Format	dos
Startup	☑ Start pool when host boots		

NOTE

If you do not see the **Physical disk device** option in the drop down menu, then your hypervisor does not support disk-based storage pools.

6. Enter the rest of the information:
   - **Target Path** - The path specifying the target device. This will be the path used for the storage pool.
   - **Source path** - The path specifying the storage device. For example, **/dev/sdb**.
   - **Format** - The type of the partition table.

- **Startup** - Whether or not the storage pool starts when the host boots.

7. Click **Create**.
   The storage pool is created. The **Create storage pool** dialog closes, and the new storage pool appears in the list of storage pools.

Additional resources

- Understanding storage pools
- Viewing storage pool information by using the web console

15.3.6. Creating LVM-based storage pools by using the web console

An LVM-based storage pool is based on volume groups, which you can manage by using the Logical Volume Manager (LVM). A volume group is a combination of multiple physical volumes that creates a single storage structure.

Before creating LVM-based storage pools, consider the following limitations:

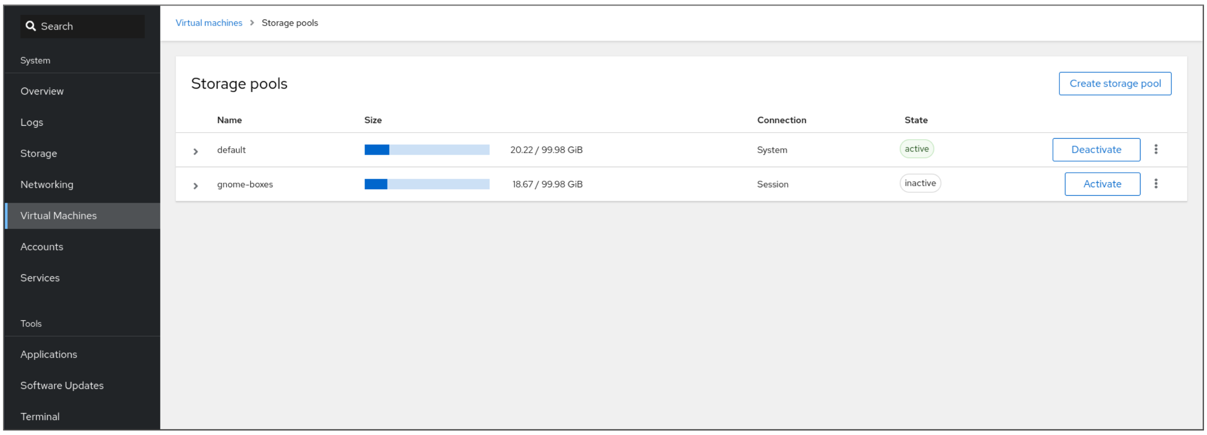
- LVM-based storage pools do not provide the full flexibility of LVM.
- **libvirt** supports thin logical volumes, but does not provide the features of thin storage pools.
- LVM-based storage pools require a full disk partition. If you activate a new partition or device by using **virsh** commands, the partition will be formatted and all data will be erased. If you are using a host's existing volume group, as in these procedures, nothing will be erased.
- To create a volume group with multiple devices, use the LVM utility instead, see How to create a volume group in Linux with LVM.
  For more detailed information about volume groups, refer to Configuring and managing logical volumes.

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 web console VM plug-in 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 RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.



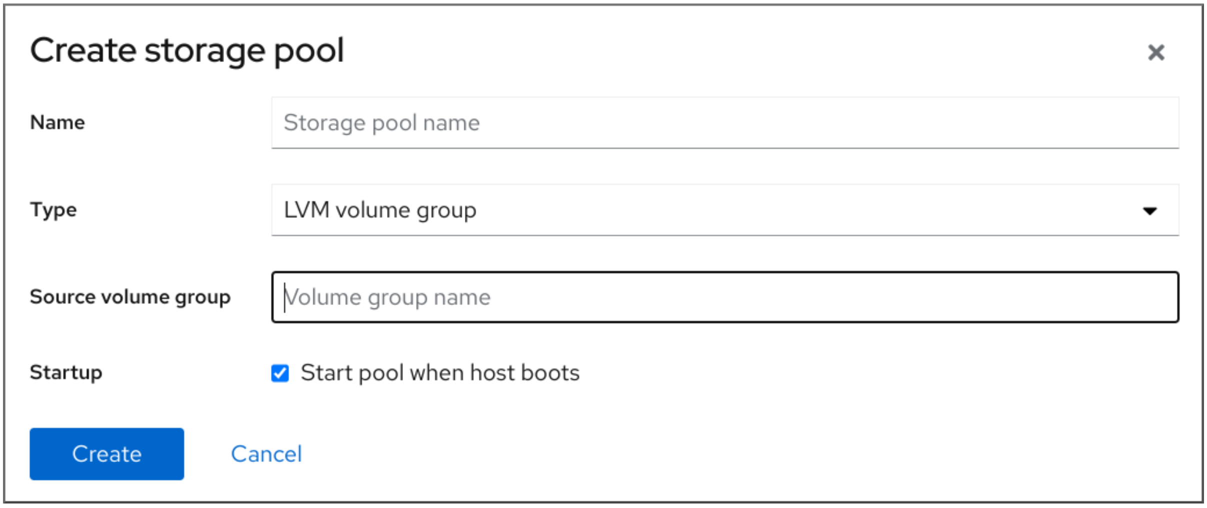
Storage pools

	Name	Size		Connection	State	
›	default		20.22 / 99.98 GiB	System	active	Deactivate ⋮
›	gnome-boxes		18.67 / 99.98 GiB	Session	inactive	Activate ⋮

3. Click **Create storage pool**.
   The **Create storage pool** dialog appears.

4. Enter a name for the storage pool.

5. In the **Type** drop down menu, select **LVM volume group**.



Create storage pool

Name: Storage pool name

Type: LVM volume group

Source volume group: Volume group name

Startup: ☑ Start pool when host boots

NOTE

If you do not see the **LVM volume group** option in the drop down menu, then your hypervisor does not support LVM-based storage pools.

6. Enter the rest of the information:
   - **Source volume group** - The name of the LVM volume group that you wish to use.
   - **Startup** - Whether or not the storage pool starts when the host boots.

7. Click **Create**.
   The storage pool is created. The **Create storage pool** dialog closes, and the new storage pool appears in the list of storage pools.

Additional resources

- Understanding storage pools
- Viewing storage pool information by using the web console

15.3.7. Removing storage pools by using the web console

If you no longer require a storage pool, or if you want to free up resources on the host or on the network to improve system performance, you can remove the storage pool.

IMPORTANT

Unless explicitly specified, deleting a storage pool does not simultaneously delete the storage volumes inside that pool.

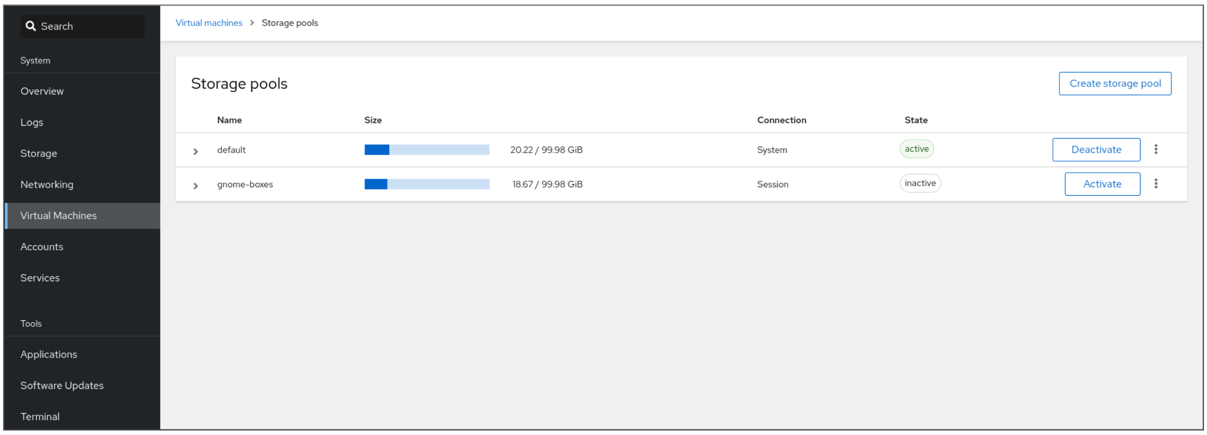
If you only want to temporarily deactivate a storage pool instead of deleting it, see Deactivating storage pools by using the web console

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 web console VM plug-in is installed on your system .
- Detach the disk from the VM.
- If you want to delete the associated storage volumes along with the pool, activate the pool.

Procedure

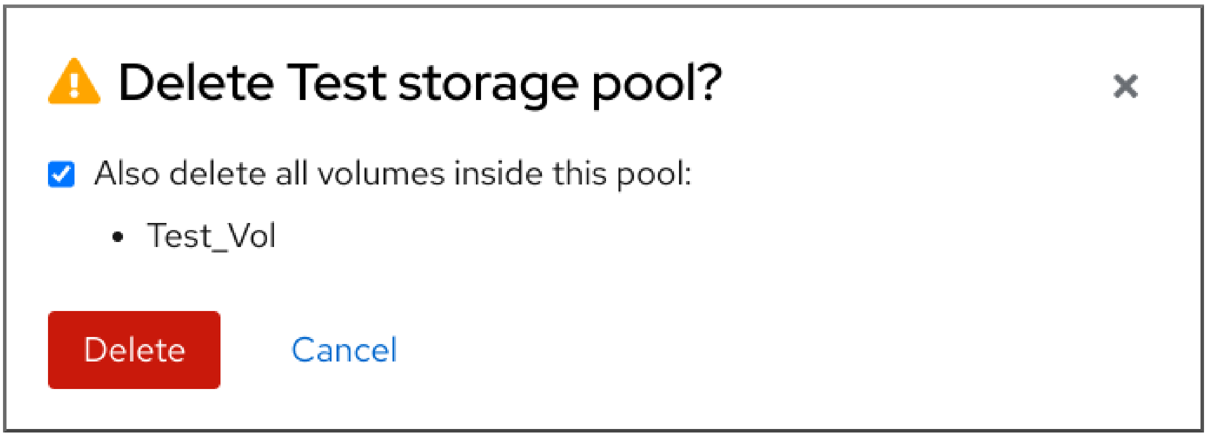
1. Click **Storage Pools** on the **Virtual Machines** tab.
   The **Storage Pools** window appears, showing a list of configured storage pools.



Storage pools

Name	Size	Connection	State
default	20.22 / 99.98 GiB	System	active
gnome-boxes	18.67 / 99.98 GiB	Session	inactive

2. Click the Menu button ⋮ of the storage pool you want to delete and click **Delete**.
   A confirmation dialog appears.



Delete Test storage pool?

☑ Also delete all volumes inside this pool:

- Test_Vol

3. Optional: To delete the storage volumes inside the pool, select the corresponding check boxes in the dialog.

4. Click **Delete**.
   The storage pool is deleted. If you had selected the checkbox in the previous step, the associated storage volumes are deleted as well.

Additional resources

- Understanding storage pools

- Viewing storage pool information by using the web console

15.3.8. Deactivating storage pools by using the web console

If you do not want to permanently delete a storage pool, you can temporarily deactivate it instead.

When you deactivate a storage pool, no new volumes can be created in that pool. However, any virtual machines (VMs) that have volumes in that pool will continue to run. This is useful for example if you want to limit the number of volumes that can be created in a pool to increase system performance.

To deactivate a storage pool by using the RHEL web console, see the following procedure.

Prerequisites

- You have installed the RHEL 9 web console.

- You have enabled the cockpit service.

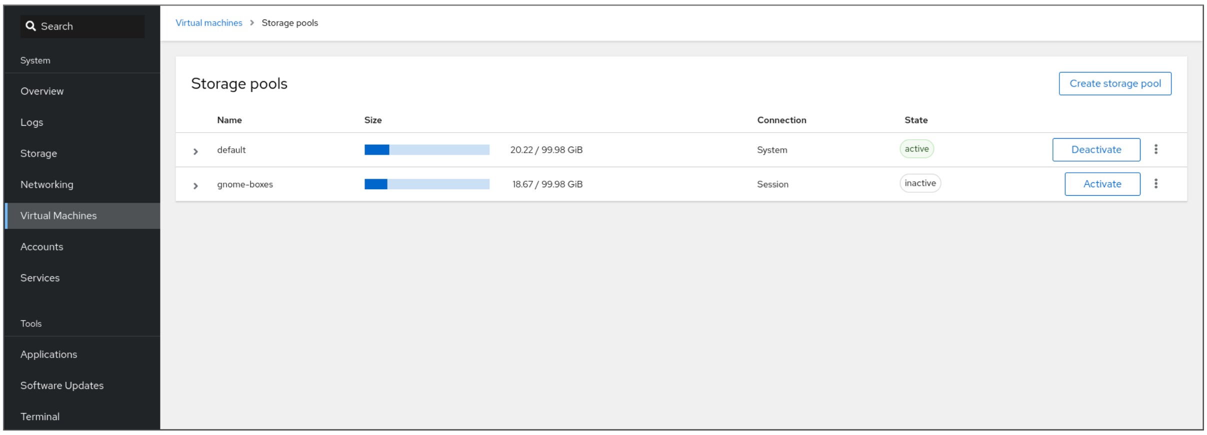
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .

- The web console VM plug-in 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. Click **Storage Pools** at the top of the Virtual Machines tab. The Storage Pools window appears, showing a list of configured storage pools.



Storage pools

Name	Size	Connection	State
default	20.22 / 99.98 GiB	System	active
gnome-boxes	18.67 / 99.98 GiB	Session	inactive

3. Click **Deactivate** on the storage pool row.
   The storage pool is deactivated.

Additional resources

- Understanding storage pools
- Viewing storage pool information by using the web console

15.4. PARAMETERS FOR CREATING STORAGE POOLS

Based on the type of storage pool you require, you can modify its XML configuration file and define a specific type of storage pool. This section provides information about the XML parameters required for creating various types of storage pools along with examples.

15.4.1. Directory-based storage pool parameters

When you want to create or modify a directory-based storage pool by using an XML configuration file, you must include certain required parameters. See the following table for more information about these parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_dir
```

Parameters

The following table provides a list of required parameters for the XML file for a directory-based storage pool.

Table 15.1. Directory-based storage pool parameters

Description	XML
The type of storage pool	`<pool type='dir'>`

Description	XML
The name of the storage pool	`<name>name</name>`

The path specifying the target. This will be the path used for the storage pool.	`<target>`
	`  <path>target_path</path>`
	`</target>`

Example

The following is an example of an XML file for a storage pool based on the /**guest_images** directory:

```
<pool type='dir'>
  <name>dirpool</name>
  <target>
    <path>/guest_images</path>
  </target>
</pool>
```

Additional resources

- Creating directory-based storage pools by using the CLI

15.4.2. Disk-based storage pool parameters

When you want to create or modify a disk-based storage pool by using an XML configuration file, you must include certain required parameters. See the following table for more information about these parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_disk
```

Parameters

The following table provides a list of required parameters for the XML file for a disk-based storage pool.

Table 15.2. Disk-based storage pool parameters

Description	XML
The type of storage pool	`<pool type='disk'>`

Description	XML
The name of the storage pool	<name>*name*</name>
The path specifying the storage device. For example, **/dev/sdb**.	<source> <path>*source_path*</path> </source>
The path specifying the target device. This will be the path used for the storage pool.	<target> <path>*target_path*</path> </target>

Example

The following is an example of an XML file for a disk-based storage pool:

```
<pool type='disk'>
  <name>phy_disk</name>
  <source>
    <device path='/dev/sdb'/>
    <format type='gpt'/>
  </source>
  <target>
    <path>/dev</path>
  </target>
</pool>
```

Additional resources

- Creating disk-based storage pools by using the CLI

15.4.3. Filesystem-based storage pool parameters

When you want to create or modify a filesystem-based storage pool by using an XML configuration file, you must include certain required parameters. See the following table for more information about these parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_fs
```

Parameters

The following table provides a list of required parameters for the XML file for a filesystem-based storage pool.

Table 15.3. Filesystem-based storage pool parameters

Description	XML
The type of storage pool	`<pool type='fs'>`
The name of the storage pool	`<name>`*name*`</name>`

The path specifying the partition. For example, **/dev/sdc1**	`<source>`
	  `<device path=`*device_path*` />`

The file system type, for example **ext4**.	`<format type=`*fs_type*` />`
	`</source>`

The path specifying the target. This will be the path used for the storage pool.	`<target>`
	  `<path>`*path-to-pool*`</path>`
	`</target>`

Example

The following is an example of an XML file for a storage pool based on the **/dev/sdc1** partition:

```
<pool type='fs'>
  <name>guest_images_fs</name>
  <source>
    <device path='/dev/sdc1'/>
    <format type='auto'/>
  </source>
  <target>
    <path>/guest_images</path>
  </target>
</pool>
```

Additional resources

- Creating filesystem-based storage pools by using the CLI

15.4.4. iSCSI-based storage pool parameters

When you want to create or modify an iSCSI-based storage pool by using an XML configuration file, you must include certain required parameters. See the following table for more information about these parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_iscsi
```

Parameters

The following table provides a list of required parameters for the XML file for an iSCSI-based storage pool.

Table 15.4. iSCSI-based storage pool parameters

Description	XML
The type of storage pool	`<pool type='iscsi'>`
The name of the storage pool	`<name>name</name>`

The name of the host	`<source>`
	`  <host name=hostname />`

The iSCSI IQN	`  <device path=iSCSI_IQN />`
	`</source>`

The path specifying the target. This will be the path used for the storage pool.	`<target>`
	`  <path>/dev/disk/by-path</path>`
	`</target>`

[Optional] The IQN of the iSCSI initiator. This is only needed when the ACL restricts the LUN to a particular initiator.	`<initiator>`
	`  <iqn name='initiator0' />`
	`</initiator>`

NOTE

The IQN of the iSCSI initiator can be determined by using the **virsh find-storage-pool-sources-as** iscsi command.

Example

The following is an example of an XML file for a storage pool based on the specified iSCSI device:

```
<pool type='iscsi'>
  <name>iSCSI_pool</name>
  <source>
    <host name='server1.example.com'/>
    <device path='iqn.2010-05.com.example.server1:iscsirhel7guest'/>
  </source>
  <target>
    <path>/dev/disk/by-path</path>
  </target>
</pool>
```

Additional resources

- Creating iSCSI-based storage pools by using the CLI

15.4.5. LVM-based storage pool parameters

When you want to create or modify an LVM-based storage pool by using an XML configuration file, you must include certain required parameters. See the following table for more information about these parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_logical
```

Parameters

The following table provides a list of required parameters for the XML file for a LVM-based storage pool.

Table 15.5. LVM-based storage pool parameters

Description	XML
The type of storage pool	`<pool type='logical'>`
The name of the storage pool	`<name>name</name>`

The path to the device for the storage pool	`<source>`
	`  <device path='device_path' />`

The name of the volume group	`  <name>VG-name</name>`

The virtual group format	`  <format type='lvm2' />`
	`</source>`

Description	XML

The target path	`<target>`
	`  <path=target_path />`
	`</target>`

NOTE

If the logical volume group is made of multiple disk partitions, there may be multiple source devices listed. For example:

```
<source>
  <device path='/dev/sda1'/>
  <device path='/dev/sdb3'/>
  <device path='/dev/sdc2'/>
  ...
</source>
```

Example

The following is an example of an XML file for a storage pool based on the specified LVM:

```
<pool type='logical'>
  <name>guest_images_lvm</name>
  <source>
    <device path='/dev/sdc'/>
    <name>libvirt_lvm</name>
    <format type='lvm2'/>
  </source>
  <target>
    <path>/dev/libvirt_lvm</path>
  </target>
</pool>
```

Additional resources

- Creating LVM-based storage pools by using the CLI

15.4.6. NFS-based storage pool parameters

When you want to create or modify an NFS-based storage pool by using an XML configuration file, you must include certain required parameters. See the following table for more information about these parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_netfs
```

–

Parameters

The following table provides a list of required parameters for the XML file for an NFS-based storage pool.

Table 15.6. NFS-based storage pool parameters

Description	XML
The type of storage pool	`<pool type='netfs'>`
The name of the storage pool	`<name>name</name>`

The hostname of the network server where the mount point is located. This can be a hostname or an IP address.	`<source>`
	`  <host name=hostname />`

The format of the storage pool	One of the following:
	`  <format type='nfs' />`
	`  <format type='cifs' />`

The directory used on the network server	`  <dir path=source_path />`
	`</source>`

The path specifying the target. This will be the path used for the storage pool.	`<target>`
	`  <path>target_path</path>`
	`</target>`

Example

The following is an example of an XML file for a storage pool based on the **/home/net_mount** directory of the **file_server** NFS server:

```
<pool type='netfs'>
  <name>nfspool</name>
  <source>
    <host name='file_server'/>
    <format type='nfs'/>
    <dir path='/home/net_mount'/>
  </source>
  <target>
```

```
    <path>/var/lib/libvirt/images/nfspool</path>
  </target>
</pool>
```

Additional resources

- Creating NFS-based storage pools by using the CLI

15.4.7. Parameters for SCSI-based storage pools with vHBA devices

To create or modify an XML configuration file for a SCSi-based storage pool that uses a virtual host adapter bus (vHBA) device, you must include certain required parameters in the XML configuration file. See the following table for more information about the required parameters.

You can use the **virsh pool-define** command to create a storage pool based on the XML configuration in a specified file. For example:

```
# virsh pool-define ~/guest_images.xml
  Pool defined from guest_images_vhba
```

Parameters

The following table provides a list of required parameters for the XML file for a SCSI-based storage pool with vHBA.

Table 15.7. Parameters for SCSI-based storage pools with vHBA devices

Description	XML
The type of storage pool	<pool type='scsi'>
The name of the storage pool	<name>*name*</name>

The identifier of the vHBA. The **parent** attribute is optional.	<source>
	  <adapter type='fc_host'
	  [parent=*parent_scsi_device*]
	  wwnn='*WWNN*'
	  wwpn='*WWPN*' />
	</source>

The target path. This will be the path used for the storage pool.	<target> <path=*target_path* /> </target>

IMPORTANT

When the **<path>** field is **/dev/**, **libvirt** generates a unique short device path for the volume device path. For example, **/dev/sdc**. Otherwise, the physical host path is used. For example, **/dev/disk/by-path/pci-0000:10:00.0-fc-0x5006016044602198-lun-0**. The unique short device path allows the same volume to be listed in multiple virtual machines (VMs) by multiple storage pools. If the physical host path is used by multiple VMs, duplicate device type warnings may occur.

NOTE

The **parent** attribute can be used in the **<adapter>** field to identify the physical HBA parent from which the NPIV LUNs by varying paths can be used. This field, **scsi_hostN**, is combined with the **vports** and **max_vports** attributes to complete the parent identification. The **parent**, **parent_wwnn**, **parent_wwpn**, or **parent_fabric_wwn** attributes provide varying degrees of assurance that after the host reboots the same HBA is used.

- If no **parent** is specified, **libvirt** uses the first **scsi_hostN** adapter that supports NPIV.
- If only the **parent** is specified, problems can arise if additional SCSI host adapters are added to the configuration.
- If **parent_wwnn** or **parent_wwpn** is specified, after the host reboots the same HBA is used.
- If **parent_fabric_wwn** is used, after the host reboots an HBA on the same fabric is selected, regardless of the **scsi_hostN** used.

Examples

The following are examples of XML files for SCSI-based storage pools with vHBA.

- A storage pool that is the only storage pool on the HBA:

```
<pool type='scsi'>
  <name>vhbapool_host3</name>
  <source>
    <adapter type='fc_host' wwnn='5001a4a93526d0a1' wwpn='5001a4ace3ee047d'/>
  </source>
  <target>
    <path>/dev/disk/by-path</path>
  </target>
</pool>
```

- A storage pool that is one of several storage pools that use a single vHBA and uses the **parent** attribute to identify the SCSI host device:

```
<pool type='scsi'>
  <name>vhbapool_host3</name>
  <source>
    <adapter type='fc_host' parent='scsi_host3' wwnn='5001a4a93526d0a1'
wwpn='5001a4ace3ee047d'/>
  </source>
  <target>
    <path>/dev/disk/by-path</path>
  </target>
</pool>
```

Additional resources

- Creating SCSI-based storage pools with vHBA devices by using the CLI

15.5. MANAGING VIRTUAL MACHINE STORAGE VOLUMES BY USING THE CLI

You can use the CLI to manage the following aspects of your storage volumes to assign storage to your virtual machines (VMs):

- View storage volume information
- Create storage volumes
- Delete storage volumes

15.5.1. Viewing storage volume information by using the CLI

By using the command line, you can view a list of all storage pools available on your host, as well as details about a specified storage pool

Procedure

1. Use the **virsh vol-list** command to list the storage volumes in a specified storage pool.

```
# virsh vol-list --pool RHEL-Storage-Pool --details
 Name                 Path                                               Type   Capacity  Allocation
---------------------------------------------------------------------------------------------
 .bash_history       /home/VirtualMachines/.bash_history       file  18.70 KiB   20.00 KiB
 .bash_logout        /home/VirtualMachines/.bash_logout        file    18.00 B    4.00 KiB
 .bash_profile       /home/VirtualMachines/.bash_profile       file   193.00 B    4.00 KiB
 .bashrc             /home/VirtualMachines/.bashrc             file   1.29 KiB    4.00 KiB
 .git-prompt.sh      /home/VirtualMachines/.git-prompt.sh      file  15.84 KiB   16.00 KiB
 .gitconfig          /home/VirtualMachines/.gitconfig          file   167.00 B    4.00 KiB
 RHEL_Volume.qcow2   /home/VirtualMachines/RHEL8_Volume.qcow2  file  60.00 GiB
13.93 GiB
```

2. Use the **virsh vol-info** command to list the storage volumes in a specified storage pool.

```
# virsh vol-info --pool RHEL-Storage-Pool --vol RHEL_Volume.qcow2
Name:           RHEL_Volume.qcow2
Type:           file
Capacity:       60.00 GiB
Allocation:     13.93 GiB
```

15.5.2. Creating and assigning storage volumes by using the CLI

To obtain a disk image and attach it to a virtual machine (VM) as a virtual disk, create a storage volume and assign its XML configuration to a the VM.

Prerequisites

- A storage pool with unallocated space is present on the host.
  - To verify, list the storage pools on the host:

    ```
    # virsh pool-list --details

    Name           State     Autostart  Persistent  Capacity    Allocation  Available
    ---------------------------------------------------------------------------------
    default        running   yes        yes         48.97 GiB   36.34 GiB   12.63 GiB
    Downloads      running   yes        yes         175.92 GiB  121.20 GiB  54.72 GiB
    VM-disks       running   yes        yes         175.92 GiB  121.20 GiB  54.72 GiB
    ```

  - If you do not have an existing storage pool, create one. For more information, see Managing storage for virtual machines.

Procedure

1. Create a storage volume by using the **virsh vol-create-as** command. For example, to create a 20 GB qcow2 volume based on the **guest-images-fs** storage pool:

   ```
   # virsh vol-create-as --pool guest-images-fs --name vm-disk1 --capacity 20 --format qcow2
   ```

   Important: Specific storage pool types do not support the **virsh vol-create-as** command and instead require specific processes to create storage volumes:

   - **iSCSI-based** - Prepare the iSCSI LUNs in advance on the iSCSI server.
   - **Multipath-based** - Use the **multipathd** command to prepare or manage the multipath.
   - **vHBA-based** - Prepare the fibre channel card in advance.

2. Create an XML file, and add the following lines in it. This file will be used to add the storage volume as a disk to a VM.

   ```
   <disk type='volume' device='disk'>
     <driver name='qemu' type='qcow2'/>
     <source pool='guest-images-fs' volume='vm-disk1'/>
     <target dev='hdk' bus='ide'/>
   </disk>
   ```

   This example specifies a virtual disk that uses the **vm-disk1** volume, created in the previous step, and sets the volume to be set up as disk **hdk** on an **ide** bus. Modify the respective parameters as appropriate for your environment.

   Important: With specific storage pool types, you must use different XML formats to describe a storage volume disk.

   - For *multipath-based* pools:

     ```
     <disk type='block' device='disk'>
     ```

```
<driver name='qemu' type='raw'/>
<source dev='/dev/mapper/mpatha' />
<target dev='sda' bus='scsi'/>
</disk>
```

- For *RBD-based storage* pools:

```
<disk type='network' device='disk'>
  <driver name='qemu' type='raw'/>
  <source protocol='rbd' name='pool/image'>
    <host name='mon1.example.org' port='6321'/>
  </source>
  <target dev='vdc' bus='virtio'/>
</disk>
```

3. Use the XML file to assign the storage volume as a disk to a VM. For example, to assign a disk defined in **~/vm-disk1.xml** to the **testguest1** VM, use the following command:

```
# virsh attach-device --config testguest1 ~/vm-disk1.xml
```

Verification

- In the guest operating system of the VM, confirm that the disk image has become available as an un-formatted and un-allocated disk.

15.5.3. Deleting storage volumes by using the CLI

To remove a storage volume from your host system, you must stop the pool and remove its XML definition.

Prerequisites

- Any virtual machine that uses the storage volume you want to delete is shut down.

Procedure

1. Use the **virsh vol-list** command to list the storage volumes in a specified storage pool.

```
# virsh vol-list --pool RHEL-SP
 Name               Path
---------------------------------------------------------------
 .bash_history       /home/VirtualMachines/.bash_history
 .bash_logout        /home/VirtualMachines/.bash_logout
 .bash_profile       /home/VirtualMachines/.bash_profile
 .bashrc             /home/VirtualMachines/.bashrc
 .git-prompt.sh      /home/VirtualMachines/.git-prompt.sh
 .gitconfig          /home/VirtualMachines/.gitconfig
 vm-disk1            /home/VirtualMachines/vm-disk1
```

2. Optional: Use the **virsh vol-wipe** command to wipe a storage volume. For example, to wipe a storage volume named **vm-disk1** associated with the storage pool **RHEL-SP**:

```
# virsh vol-wipe --pool RHEL-SP vm-disk1
Vol vm-disk1 wiped
```

3. Use the **virsh vol-delete** command to delete a storage volume. For example, to delete a storage volume named **vm-disk1** associated with the storage pool **RHEL-SP**:

```
# virsh vol-delete --pool RHEL-SP vm-disk1
Vol vm-disk1 deleted
```

Verification

- Use the **virsh vol-list** command again to verify that the storage volume was deleted.

```
# virsh vol-list --pool RHEL-SP
 Name                 Path
---------------------------------------------------------------
 .bash_history        /home/VirtualMachines/.bash_history
 .bash_logout         /home/VirtualMachines/.bash_logout
 .bash_profile        /home/VirtualMachines/.bash_profile
 .bashrc              /home/VirtualMachines/.bashrc
 .git-prompt.sh       /home/VirtualMachines/.git-prompt.sh
 .gitconfig           /home/VirtualMachines/.gitconfig
```

15.6. MANAGING VIRTUAL DISK IMAGES BY USING THE CLI

Virtual disk images are a type of virtual storage volumes and provide storage to virtual machines (VMs) in a similar way as hard drives provide storage for physical machines.

When creating a new VM , **libvirt** creates a new disk image automatically, unless you specify otherwise. However, depending on your use case, you might want to create and manage a disk image separately from the VM.

15.6.1. Creating a virtual disk image by using qemu-img

If you require creating a new virtual disk image separately from a new virtual machine (VM) and creating a storage volume is not viable for you, you can use the **qemu-img** command-line utility.

Procedure

- Create a virtual disk image by using the **qemu-img** utility:

```
# qemu-img create -f <format> <image-name> <size>
```

For example, the following command creates a qcow2 disk image named *test-image* with the size of 30 gigabytes:

```
# qemu-img create -f qcow2 test-image 30G

Formatting 'test-img', fmt=qcow2 cluster_size=65536 extended_l2=off compression_type=zlib
size=32212254720 lazy_refcounts=off refcount_bits=16
```

Verification

- Display the information about the image you created and check that it has the required size and does not report any corruption:

  ```
  # qemu-img info <test-img>
  image: test-img
  file format: qcow2
  virtual size: 30 GiB (32212254720 bytes)
  disk size: 196 KiB
  cluster_size: 65536
  Format specific information:
      compat: 1.1
      compression type: zlib
      lazy refcounts: false
      refcount bits: 16
      corrupt: false
      extended l2: false
  ```

Additional resources

- Creating and assigning storage volumes by using the CLI
- Adding new disks to virtual machines by using the web console
- **qemu-img** man page on your system

15.6.2. Checking the consistency of a virtual disk image

Before attaching a disk image to a virtual machine (VM), ensure that the disk image does not have problems, such as corruption or high fragmentation. To do so, you can use the **qemu-img check** command.

If needed, you can also use this command to attempt repairing the disk image.

Prerequisites

- Any virtual machines (VMs) that use the disk image must be shut down.

Procedure

1. Use the **qemu-img check** command on the image you want to test. For example:

   ```
   # qemu-img check <test-name.qcow2>

   No errors were found on the image.
   327434/327680 = 99.92% allocated, 0.00% fragmented, 0.00% compressed clusters
   Image end offset: 21478375424
   ```

   If the check finds problems on the disk image, the output of the command looks similar to the following:

   ```
   167 errors were found on the image.
   Data may be corrupted, or further writes to the image may corrupt it.
   ```

```
453368 leaked clusters were found on the image.
This means waste of disk space, but no harm to data.

259 internal errors have occurred during the check.
Image end offset: 21478375424
```

2. To attempt repairing the detected issues, use the **qemu-img check** command with the **-r all** option. Note, however, that this might fix only some of the problems.

   > **WARNING**
   >
   > Repairing the disk image can cause data corruption or other issues. Back up the disk image before attempting the repair.

   ```
   # qemu-img check -r all <test-name.qcow2>

   [...]
   122 errors were found on the image.
   Data may be corrupted, or further writes to the image may corrupt it.

   250 internal errors have occurred during the check.
   Image end offset: 27071414272
   ```

   This output indicates the number of problems found on the disk image after the repair.

3. If further disk image repairs are required, you can use various **libguestfs** tools in the **guestfish** shell.

Additional resources

- **qemu-img** and **guestfish** man pages on your system

15.6.3. Resizing a virtual disk image

If an existing disk image requires additional space, you can use the **qemu-img resize** utility to change the size of the image to fit your use case.

Prerequisites

- You have created a backup of the disk image.
- Any virtual machines (VMs) that use the disk image must be shutdown.

> **WARNING**
>
> Resizing the disk image of a running VM can cause data corruption or other issues.

- The hard disk of the host has sufficient free space for the intended disk image size.
- **Optional:** You have ensured that the disk image does not have data corruption or similar problems. For instructions, see Checking the consistency of a virtual disk image .

Procedure

1. Determine the location of the disk image file for the VM you want to resize. For example:

```
# virsh domblklist <vm-name>

 Target   Source
----------------------------------------------------------
 vda      /home/username/disk-images/example-image.qcow2
```

2. **Optional:** Back up the current disk image.

```
# cp <example-image.qcow2> <example-image-backup.qcow2>
```

3. Use the **qemu-img resize** utility to resize the image.
   For example, to increase the *<example-image.qcow2>* size by 10 gigabytes:

```
# qemu-img resize <example-image.qcow2> +10G
```

4. Resize the file system, partitions, or physical volumes inside the disk image to use the additional space. To do so in a RHEL guest operating system, use the instructions in Managing storage devices and Managing file systems.

Verification

1. Display information about the resized image and see if it has the intended size:

```
# qemu-img info <converted-image.qcow2>

image: converted-image.qcow2
file format: qcow2
virtual size: 30 GiB (32212254720 bytes)
disk size: 196 KiB
cluster_size: 65536
Format specific information:
    compat: 1.1
    compression type: zlib
    lazy refcounts: false
    refcount bits: 16
    corrupt: false
    extended l2: false
```

2. Check the resized disk image for potential errors. For instructions, see Checking the consistency of a virtual disk image.

Additional resources

- **qemu-img** man page on your system
- Managing storage devices
- Managing file systems

15.6.4. Converting between virtual disk image formats

You can convert the virtual disk image to a different format by using the **qemu-img convert** command. For example, converting between virtual disk image formats might be necessary if you want to attach the disk image to a virtual machine (VM) running on a different hypervisor.

Prerequisites

- Any virtual machines (VMs) that use the disk image must be shut down.
- The source disk image format must be supported for conversion by QEMU. For a detailed list, see Supported disk image formats .

Procedure

- Use the **qemu-img convert** command to convert an existing virtual disk image to a different format. For example, to convert a *raw* disk image to a *QCOW2* disk image:

```
# qemu-img convert -f raw <original-image.img> -O qcow2 <converted-image.qcow2>
```

Verification

1. Display information about the converted image and see if it has the intended format and size.

```
# qemu-img info <converted-image.qcow2>

image: converted-image.qcow2
file format: qcow2
virtual size: 30 GiB (32212254720 bytes)
disk size: 196 KiB
cluster_size: 65536
Format specific information:
    compat: 1.1
    compression type: zlib
    lazy refcounts: false
    refcount bits: 16
    corrupt: false
    extended l2: false
```

2. Check the disk image for potential errors. for instructions, see Checking the consistency of a virtual disk image.

Additional resources

- Checking the consistency of a virtual disk image
- Supported disk image formats
- **qemu-img** man page on your system

15.6.5. Supported disk image formats

To run a virtual machine (VM) on RHEL, you must use a disk image with a supported format. You can also convert certain unsupported disk images to a supported format.

Supported disk image formats for VMs

You can use disk images that use the following formats to run VMs in RHEL:

- **qcow2** - Provides certain additional features, such as compression.
- **raw** - Might provide better performance.
- **luks** - Disk images encrypted by using the Linux Unified Key Setup (LUKS) specification.

Supported disk image formats for conversion

- If required, you can convert your disk images between the **raw** and **qcow2** formats by using the **qemu-img convert** command.
- If you require converting a **vmdk** disk image to a **raw** or **qcow2** format, convert the VM that uses the disk to KVM by using the **virt-v2v** utility.
- To convert other disk image formats to **raw** or **qcow2**, you can use the **qemu-img convert** command. For a list of formats that work with this command, see the QEMU documentation. Note that in most cases, converting the disk image format of a non-KVM virtual machine to **qcow2** or **raw** is not sufficient for the VM to correctly run on RHEL KVM. In addition to converting the disk image, corresponding drivers must be installed and configured in the guest operating system of the VM. For supported hypervisor conversion, use the **virt-v2v** utility.

Additional resources

- Converting virtual machines from other hypervisors to KVM with virt-v2v in RHEL 7, RHEL 8, and RHEL 9
- Converting between virtual disk image formats

15.7. MANAGING VIRTUAL MACHINE STORAGE VOLUMES BY USING THE WEB CONSOLE

By using the RHEL, you can manage the storage volumes used to allocate storage to your virtual machines (VMs).

You can use the RHEL web console to:

- Create storage volumes.
- Remove storage volumes.

15.7.1. Creating storage volumes by using the web console

To create a functioning virtual machine (VM) you require a local storage device assigned to the VM that can store the VM image and VM-related data. You can create a storage volume in a storage pool and assign it to a VM as a storage disk.

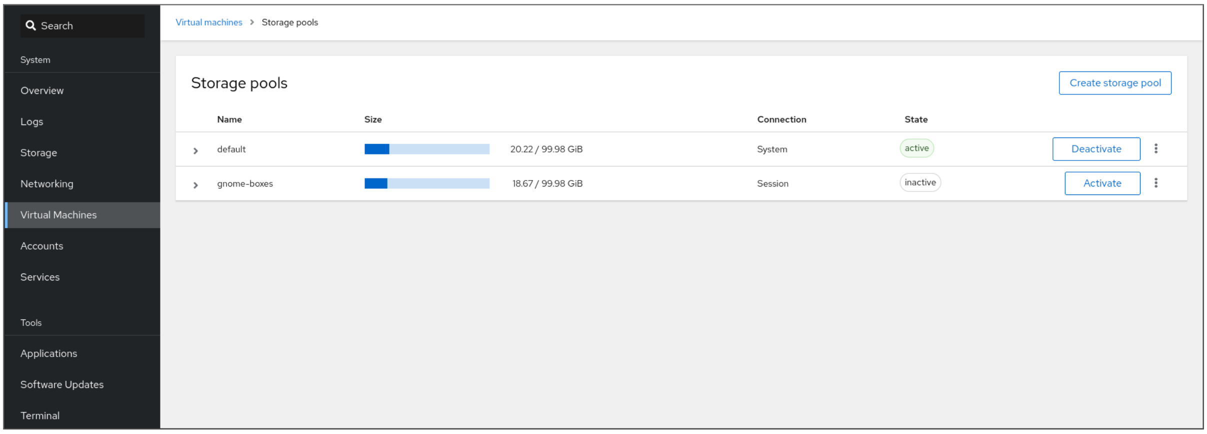
To create storage volumes by using the web console, see the following procedure.

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 web console VM plug-in is installed on your system.

Procedure

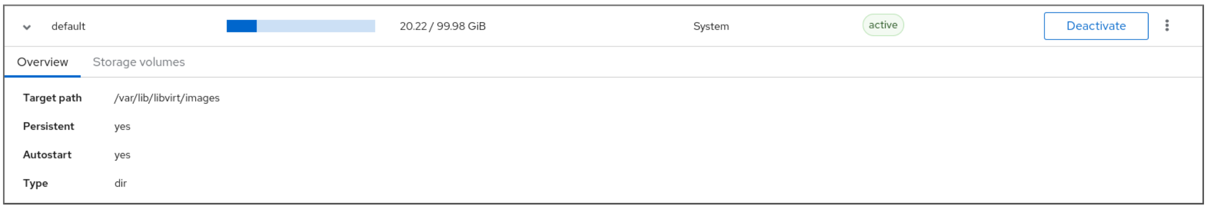
1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console.
2. Click **Storage Pools** at the top of the Virtual Machines tab. The Storage Pools window appears, showing a list of configured storage pools.



Storage pools

Name	Size		Connection	State		
default		20.22 / 99.98 GiB	System	active	Deactivate	⋮
gnome-boxes		18.67 / 99.98 GiB	Session	inactive	Activate	⋮

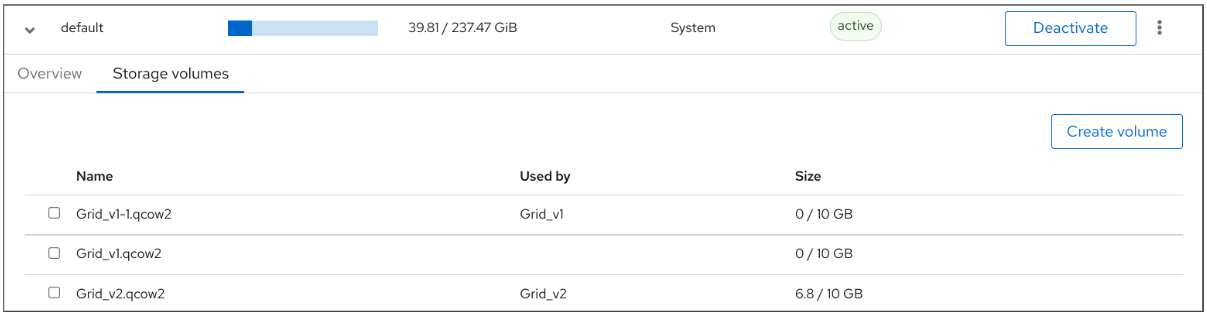
3. In the **Storage Pools** window, click the storage pool from which you want to create a storage volume.
   The row expands to reveal the Overview pane with basic information about the selected storage pool.



Target path	/var/lib/libvirt/images
Persistent	yes
Autostart	yes
Type	dir

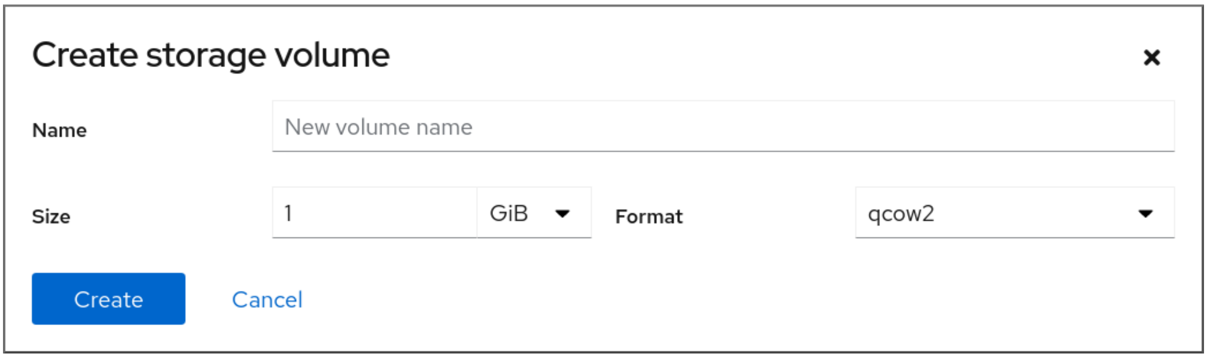
4. Click **Storage Volumes** next to the Overview tab in the expanded row.

The Storage Volume tab appears with basic information about existing storage volumes, if any.



	Name	Used by	Size
□	Grid_v1-1.qcow2	Grid_v1	0 / 10 GB
□	Grid_v1.qcow2		0 / 10 GB
□	Grid_v2.qcow2	Grid_v2	6.8 / 10 GB

5. Click **Create Volume**.
   The **Create storage volume** dialog appears.



Name: New volume name

Size: 1 GiB

Format: qcow2

6. Enter the following information in the Create Storage Volume dialog:
   - **Name** - The name of the storage volume.
   - **Size** - The size of the storage volume in MiB or GiB.
   - **Format** - The format of the storage volume. The supported types are **qcow2** and **raw**.
7. Click **Create**.
   The storage volume is created, the Create Storage Volume dialog closes, and the new storage volume appears in the list of storage volumes.

Additional resources

- Understanding storage volumes
- Adding new disks to virtual machines by using the web console

15.7.2. Removing storage volumes by using the web console

You can remove storage volumes to free up space in the storage pool, or to remove storage items associated with defunct virtual machines (VMs).

To remove storage volumes by using the RHEL web console, see the following procedure.

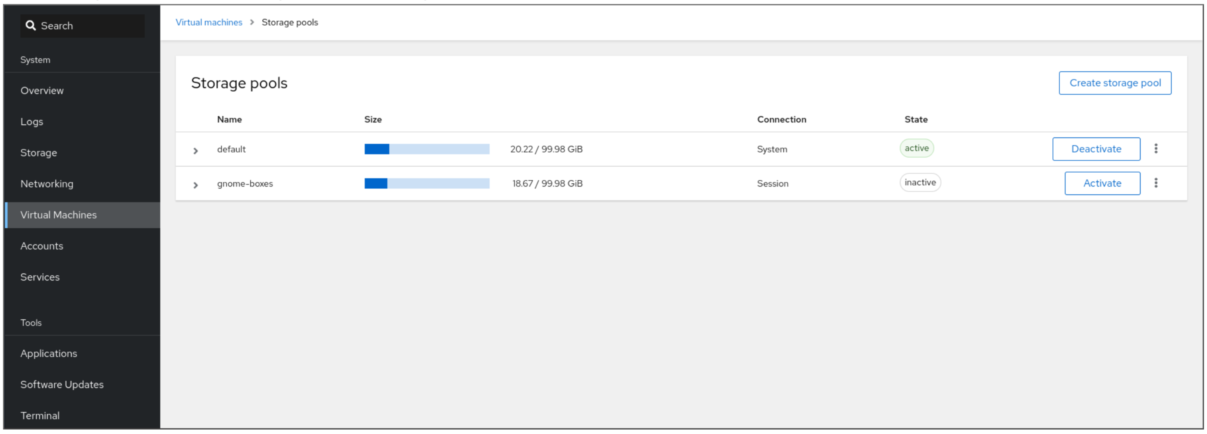
Prerequisites

- 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 web console VM plug-in is installed on your system .
- Any virtual machine that uses the storage volume you want to delete is shut down.

Procedure

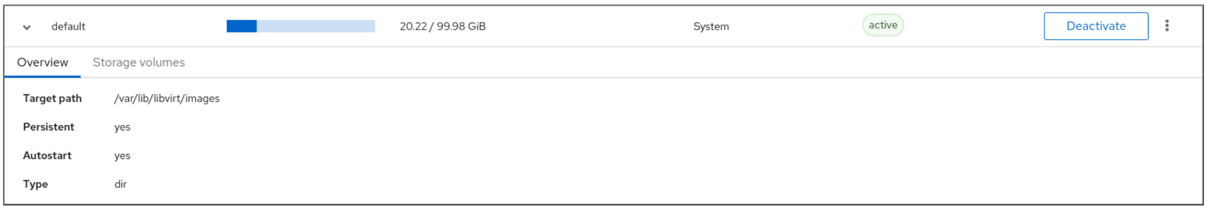
1. Click **Storage Pools** at the top of the Virtual Machines tab. The Storage Pools window appears, showing a list of configured storage pools.



Storage pools

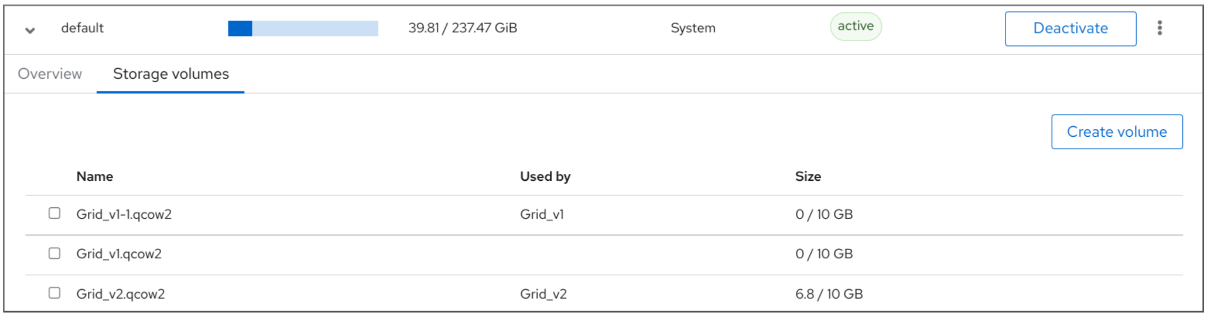
	Name	Size		Connection	State
›	default		20.22 / 99.98 GiB	System	active
›	gnome-boxes		18.67 / 99.98 GiB	Session	inactive

2. In the **Storage Pools** window, click the storage pool from which you want to remove a storage volume.
   The row expands to reveal the Overview pane with basic information about the selected storage pool.



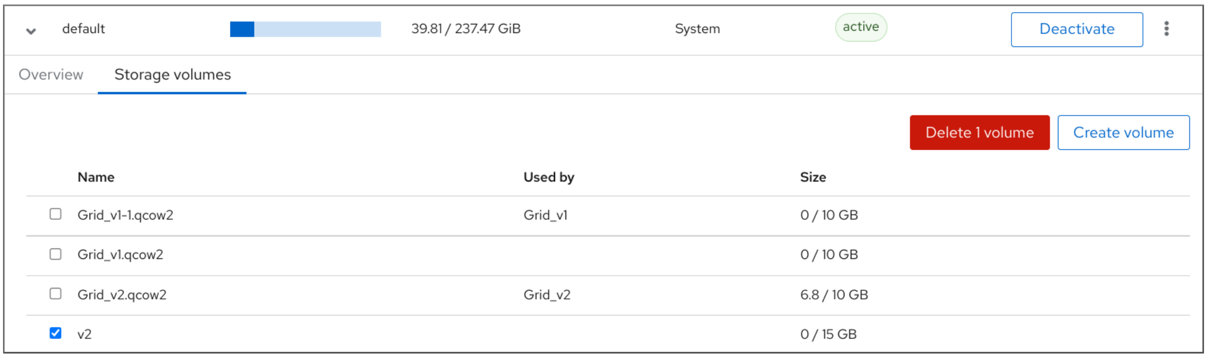
Target path	/var/lib/libvirt/images
Persistent	yes
Autostart	yes
Type	dir

3. Click **Storage Volumes** next to the Overview tab in the expanded row.
   The Storage Volume tab appears with basic information about existing storage volumes, if any.



	Name	Used by	Size
□	Grid_v1-1.qcow2	Grid_v1	0 / 10 GB
□	Grid_v1.qcow2		0 / 10 GB
□	Grid_v2.qcow2	Grid_v2	6.8 / 10 GB

4. Select the storage volume you want to remove.



	Name	Used by	Size
□	Grid_v1-1.qcow2	Grid_v1	0 / 10 GB
□	Grid_v1.qcow2		0 / 10 GB
□	Grid_v2.qcow2	Grid_v2	6.8 / 10 GB
☑	v2		0 / 15 GB

5. Click **Delete 1 Volume**

Additional resources

- Understanding storage volumes

15.8. MANAGING VIRTUAL MACHINE STORAGE DISKS BY USING THE WEB CONSOLE

By using RHEL, you can manage the storage disks that are attached to your virtual machines (VMs).

You can use the RHEL web console to:

- View VM disk information.
- Add new disks to a VM .
- Attach disks to a VM .
- Detach disks from a VM .

15.8.1. Viewing virtual machine disk information in the web console

By using the web console, you can view detailed information about disks assigned to a selected virtual machine (VM).

Prerequisites

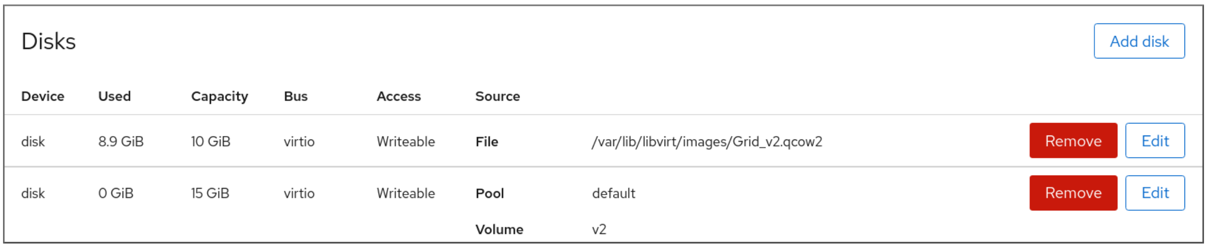
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The web console VM plug-in is installed on your system.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. Click the VM whose information you want to see.

A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM’s graphical interface.

3. Scroll to **Disks**.
The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.



Disks

Device	Used	Capacity	Bus	Access	Source		
disk	8.9 GiB	10 GiB	virtio	Writeable	**File**	/var/lib/libvirt/images/Grid_v2.qcow2	Remove Edit
disk	0 GiB	15 GiB	virtio	Writeable	**Pool** **Volume**	default v2	Remove Edit

The information includes the following:

- **Device** - The device type of the disk.
- **Used** - The amount of disk currently allocated.
- **Capacity** - The maximum size of the storage volume.
- **Bus** - The type of disk device that is emulated.
- **Access** - Whether the disk is **Writeable** or **Read-only**. For **raw** disks, you can also set the access to **Writeable and shared**.
- **Source** - The disk device or file.

Additional resources

- Viewing virtual machine information by using the web console

15.8.2. Adding new disks to virtual machines by using the web console

You can add new disks to virtual machines (VMs) by creating a new storage volume and attaching it to a VM by using the RHEL 9 web console.

Prerequisites

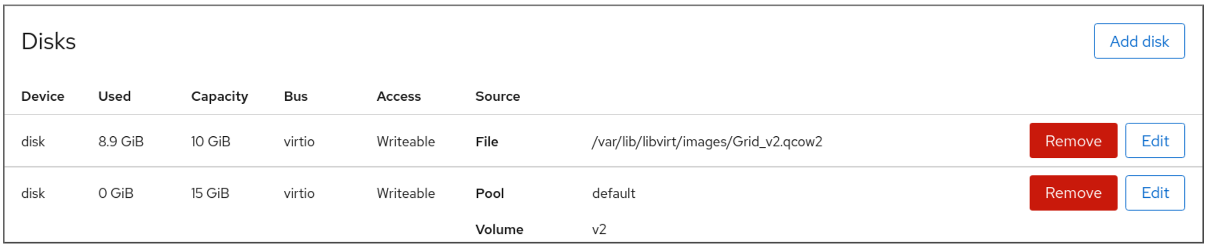
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
For instructions, see Installing and enabling the web console .
- The web console VM plug-in is installed on your system .

Procedure

1. Log in to the RHEL 9 web console.
For details, see Logging in to the web console .

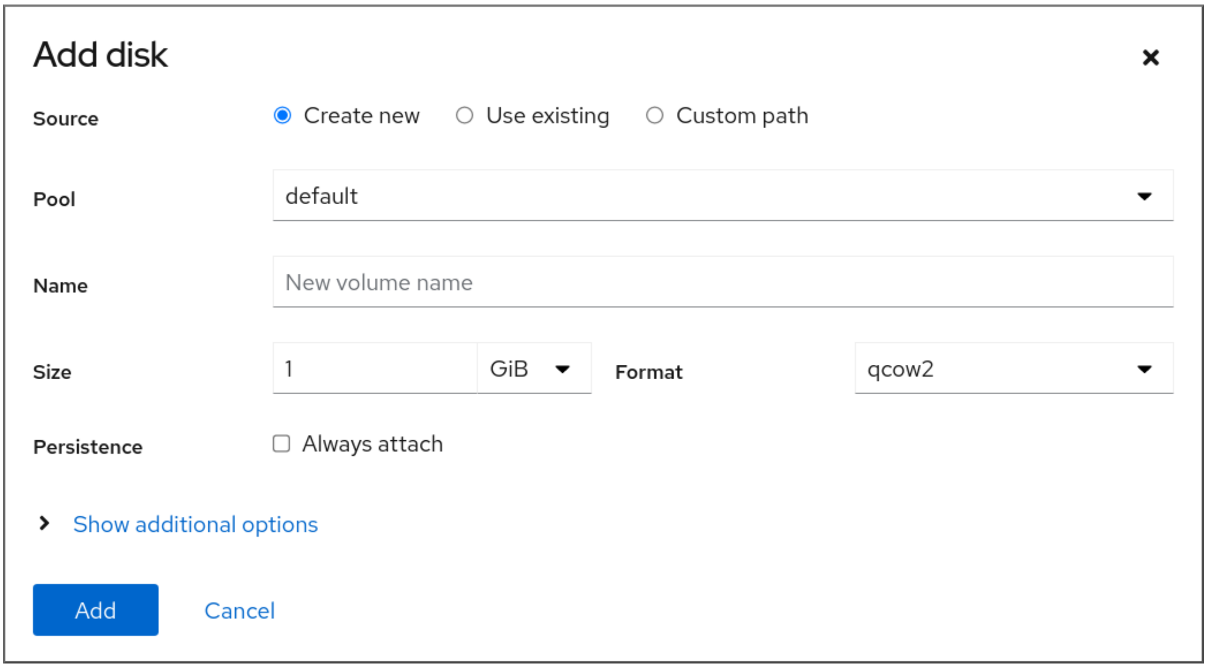
2. In the **Virtual Machines** interface, click the VM for which you want to create and attach a new disk.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

3. Scroll to **Disks**.
   The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.



Device	Used	Capacity	Bus	Access	Source		
disk	8.9 GiB	10 GiB	virtio	Writeable	**File**	/var/lib/libvirt/images/Grid_v2.qcow2	Remove Edit
disk	0 GiB	15 GiB	virtio	Writeable	**Pool** **Volume**	default v2	Remove Edit

4. Click **Add Disk**.
   The Add Disk dialog appears.



Source ● Create new ○ Use existing ○ Custom path

Pool: default

Name: New volume name

Size: 1 GiB Format: qcow2

Persistence □ Always attach

5. Select the *Create New* option.

6. Configure the new disk.

   - **Pool** - Select the storage pool from which the virtual disk will be created.
   - **Name** - Enter a name for the virtual disk that will be created.
   - **Size** - Enter the size and select the unit (MiB or GiB) of the virtual disk that will be created.
   - **Format** - Select the format for the virtual disk that will be created. The supported types are **qcow2** and **raw**.
   - **Persistence** - If checked, the virtual disk is persistent. If not checked, the virtual disk is transient.

NOTE

Transient disks can only be added to VMs that are running.

- **Additional Options** - Set additional configurations for the virtual disk.
  - **Cache** - Select the cache mechanism.
  - **Bus** - Select the type of disk device to emulate.
  - **Disk Identifier** - Set an identifier for the attached disk that you can use for multipath storage setups. The identifier is also useful when using proprietary software licensed to specific disk serial numbers.

7. Click **Add**.
   The virtual disk is created and connected to the VM.

Additional resources

- Viewing virtual machine disk information in the web console
- Attaching existing disks to virtual machines by using the web console
- Detaching disks from virtual machines by using the web console

15.8.3. Attaching existing disks to virtual machines by using the web console

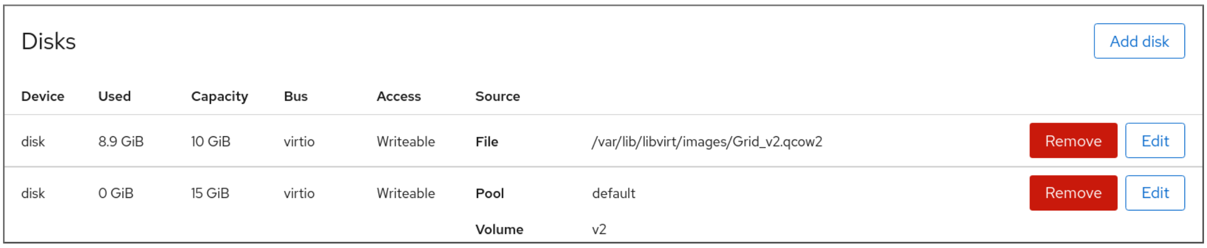
By using the web console, you can attach existing storage volumes as disks to a virtual machine (VM).

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 web console VM plug-in is installed on your system.

Procedure

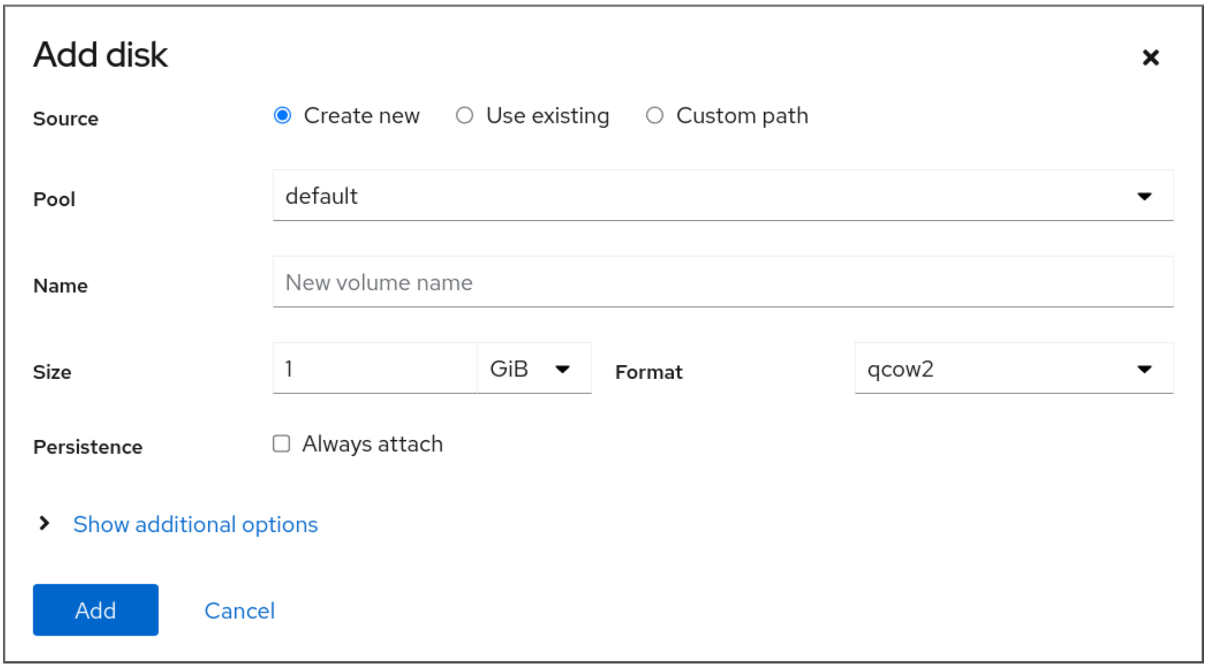
1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the VM for which you want to create and attach a new disk.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.
3. Scroll to **Disks**.
   The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.



Disks

Device	Used	Capacity	Bus	Access	Source	
disk	8.9 GiB	10 GiB	virtio	Writeable	File	/var/lib/libvirt/images/Grid_v2.qcow2
disk	0 GiB	15 GiB	virtio	Writeable	Pool Volume	default v2

4. Click **Add Disk**.
   The Add Disk dialog appears.



Add disk

Source: ● Create new ○ Use existing ○ Custom path

Pool: default

Name: New volume name

Size: 1 GiB Format: qcow2

Persistence: □ Always attach

5. Click the **Use Existing** radio button.
   The appropriate configuration fields appear in the Add Disk dialog.

6. Configure the disk for the VM.

   - **Pool** - Select the storage pool from which the virtual disk will be attached.
   - **Volume** - Select the storage volume that will be attached.
   - **Persistence** - Available when the VM is running. Select the **Always attach** checkbox to make the virtual disk persistent. Clear the checkbox to make the virtual disk transient.
   - **Additional Options** - Set additional configurations for the virtual disk.
     - **Cache** - Select the cache mechanism.
     - **Bus** - Select the type of disk device to emulate.
     - **Disk Identifier** - Set an identifier for the attached disk that you can use for multipath storage setups. The identifier is also useful when using proprietary software licensed to specific disk serial numbers.

7. Click **Add**
   The selected virtual disk is attached to the VM.

Additional resources

- Viewing virtual machine disk information in the web console
- Adding new disks to virtual machines by using the web console
- Detaching disks from virtual machines by using the web console

15.8.4. Detaching disks from virtual machines by using the web console

By using the web console, you can detach disks from virtual machines (VMs).

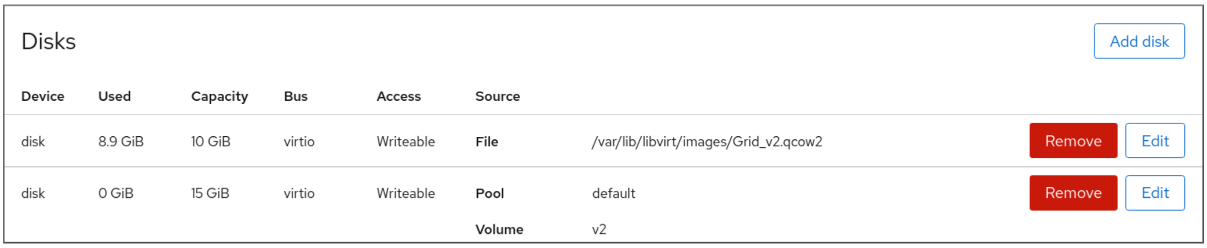
Prerequisites

- The web console VM plug-in is installed on your system .

Procedure

1. In the **Virtual Machines** interface, click the VM from which you want to detach a disk.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

2. Scroll to **Disks**.
   The Disks section displays information about the disks assigned to the VM, as well as options to **Add** or **Edit** disks.



Device	Used	Capacity	Bus	Access	Source	
disk	8.9 GiB	10 GiB	virtio	Writeable	File	/var/lib/libvirt/images/Grid_v2.qcow2
disk	0 GiB	15 GiB	virtio	Writeable	Pool	default
					Volume	v2

3. On the right side of the row for the disk that you want to detach, click the Menu button ⋮ .

4. In the drop-down menu that appears, click the **Remove** button.
   A **Remove disk from VM?** confirmation dialog box appears.

5. In the confirmation dialog box, click **Remove**. Optionally, if you also want to remove the disk image, click **Remove and delete file**.
   The virtual disk is detached from the VM.

Additional resources

- Viewing virtual machine disk information in the web console
- Adding new disks to virtual machines by using the web console
- Attaching existing disks to virtual machines by using the web console

15.9. SECURING ISCSI STORAGE POOLS WITH LIBVIRT SECRETS

Username and password parameters can be configured with **virsh** to secure an iSCSI storage pool. You can configure this before or after you define the pool, but the pool must be started for the authentication settings to take effect.

The following provides instructions for securing iSCSI-based storage pools with **libvirt** secrets.

NOTE

This procedure is required if a ***user_ID*** and ***password*** were defined when creating the iSCSI target.

Prerequisites

- Ensure that you have created an iSCSI-based storage pool. For more information, see Creating iSCSI-based storage pools by using the CLI.

Procedure

1. Create a libvirt secret file with a challenge-handshake authentication protocol (CHAP) user name. For example:

```
<secret ephemeral='no' private='yes'>
   <description>Passphrase for the iSCSI example.com server</description>
   <usage type='iscsi'>
      <target>iscsirhel7secret</target>
   </usage>
</secret>
```

2. Define the libvirt secret with the **virsh secret-define** command:

```
# virsh secret-define secret.xml
```

3. Verify the UUID with the **virsh secret-list** command:

```
# virsh secret-list
UUID                                  Usage
--------------------------------------------------------------
2d7891af-20be-4e5e-af83-190e8a922360  iscsi iscsirhel7secret
```

4. Assign a secret to the UUID in the output of the previous step using the **virsh secret-set-value** command. This ensures that the CHAP username and password are in a libvirt-controlled secret list. For example:

```
# virsh secret-set-value --interactive 2d7891af-20be-4e5e-af83-190e8a922360
Enter new value for secret:
Secret value set
```

5. Add an authentication entry in the storage pool's XML file using the **virsh edit** command, and add an **<auth>** element, specifying **authentication type**, **username**, and **secret usage**. For example:

```
<pool type='iscsi'>
  <name>iscsirhel7pool</name>
   <source>
     <host name='192.0.2.1'/>
     <device path='iqn.2010-05.com.example.server1:iscsirhel7guest'/>
     <auth type='chap' username='_example-user_'>
     <secret usage='iscsirhel7secret'/>
   </auth>
  </source>
 <target>
  <path>/dev/disk/by-path</path>
 </target>
</pool>
```

NOTE

The **<auth>** sub-element exists in different locations within the virtual machine's **<pool>** and **<disk>** XML elements. For a **<pool>**, **<auth>** is specified within the **<source>** element, as this describes where to find the pool sources, since authentication is a property of some pool sources (iSCSI and RBD). For a **<disk>**, which is a sub-element of a domain, the authentication to the iSCSI or RBD disk is a property of the disk. In addition, the **<auth>** sub-element for a disk differs from that of a storage pool.

```
<auth username='redhat'>
 <secret type='iscsi' usage='iscsirhel7secret'/>
</auth>
```

6. To activate the changes, activate the storage pool. If the pool has already been started, stop and restart the storage pool:

```
# virsh pool-destroy iscsirhel7pool
# virsh pool-start iscsirhel7pool
```

15.10. CREATING VHBAS

A virtual host bus adapter (vHBA) device connects the host system to an SCSI device and is required for creating an SCSI-based storage pool.

You can create a vHBA device by defining it in an XML configuration file.

Procedure

1. Locate the HBAs on your host system, by using the **virsh nodedev-list --cap vports** command. The following example shows a host that has two HBAs that support vHBA:

```
# virsh nodedev-list --cap vports
scsi_host3
scsi_host4
```

2. View the HBA's details, by using the **virsh nodedev-dumpxml *HBA_device*** command.

```
# virsh nodedev-dumpxml scsi_host3
```

The output from the command lists the **<name>**, **<wwnn>**, and **<wwpn>** fields, which are used to create a vHBA. **<max_vports>** shows the maximum number of supported vHBAs. For example:

```
<device>
  <name>scsi_host3</name>
  <path>/sys/devices/pci0000:00/0000:00:04.0/0000:10:00.0/host3</path>
  <parent>pci_0000_10_00_0</parent>
  <capability type='scsi_host'>
    <host>3</host>
    <unique_id>0</unique_id>
    <capability type='fc_host'>
      <wwnn>20000000c9848140</wwnn>
      <wwpn>10000000c9848140</wwpn>
      <fabric_wwn>2002000573de9a81</fabric_wwn>
    </capability>
    <capability type='vport_ops'>
      <max_vports>127</max_vports>
      <vports>0</vports>
    </capability>
  </capability>
</device>
```

In this example, the **<max_vports>** value shows there are a total 127 virtual ports available for use in the HBA configuration. The **<vports>** value shows the number of virtual ports currently being used. These values update after creating a vHBA.

3. Create an XML file similar to one of the following for the vHBA host. In these examples, the file is named **vhba_host3.xml**.
   This example uses **scsi_host3** to describe the parent vHBA.

```
<device>
  <parent>scsi_host3</parent>
  <capability type='scsi_host'>
    <capability type='fc_host'>
    </capability>
  </capability>
</device>
```

This example uses a WWNN/WWPN pair to describe the parent vHBA.

```
<device>
  <name>vhba</name>
  <parent wwnn='20000000c9848140' wwpn='10000000c9848140'/>
  <capability type='scsi_host'>
    <capability type='fc_host'>
    </capability>
  </capability>
</device>
```

NOTE

The WWNN and WWPN values must match those in the HBA details seen in the previous step.

The **<parent>** field specifies the HBA device to associate with this vHBA device. The details in the **<device>** tag are used in the next step to create a new vHBA device for the host. For more information about the **nodedev** XML format, see the libvirt upstream pages.

NOTE

The **virsh** command does not provide a way to define the **parent_wwnn**, **parent_wwpn**, or **parent_fabric_wwn** attributes.

4. Create a VHBA based on the XML file created in the previous step by using the **virsh nodev-create** command.

```
# virsh nodedev-create vhba_host3
Node device scsi_host5 created from vhba_host3.xml
```

Verification

- Verify the new vHBA's details (scsi_host5) by using the **virsh nodedev-dumpxml** command:

```
# virsh nodedev-dumpxml scsi_host5
<device>
  <name>scsi_host5</name>
  <path>/sys/devices/pci0000:00/0000:00:04.0/0000:10:00.0/host3/vport-3:0-0/host5</path>
  <parent>scsi_host3</parent>
  <capability type='scsi_host'>
    <host>5</host>
    <unique_id>2</unique_id>
    <capability type='fc_host'>
      <wwnn>5001a4a93526d0a1</wwnn>
      <wwpn>5001a4ace3ee047d</wwpn>
      <fabric_wwn>2002000573de9a81</fabric_wwn>
    </capability>
  </capability>
</device>
```

Additional resources

- Creating SCSI-based storage pools with vHBA devices by using the CLI

CHAPTER 16. MANAGING GPU DEVICES IN VIRTUAL MACHINES

To prepare your virtual machine (VM) for running AI workloads or to enhance the graphical performance of the VM, you can assign a RHEL host GPU to the VM.

- You can detach the GPU from the host and pass full control of the GPU directly to the VM.
- You can create multiple mediated devices from a physical GPU, and assign these devices as virtual GPUs (vGPUs) to multiple guests. This is currently only supported on selected NVIDIA GPUs.

IMPORTANT

GPU assignment is currently only supported on Intel 64 and AMD64 systems.

16.1. ASSIGNING A GPU TO A VIRTUAL MACHINE

To access and control GPUs that are attached to the host system, you must configure the host system to pass direct control of the GPU to the virtual machine (VM).

NOTE

If you are looking for information about assigning a virtual GPU, see Managing NVIDIA vGPU devices.

Prerequisites

- You must enable IOMMU support on the host machine kernel.
  - On an Intel host, you must enable VT-d:
    1. Regenerate the GRUB configuration with the **intel_iommu=on** and **iommu=pt** parameters:

       ```
       # grubby --args="intel_iommu=on iommu=pt" --update-kernel DEFAULT
       ```

    2. Reboot the host.
  - On an AMD host, you must enable AMD-Vi.
    Note that on AMD hosts, IOMMU is enabled by default, you can add **iommu=pt** to switch it to pass-through mode:
    1. Regenerate the GRUB configuration with the **iommu=pt** parameter:

       ```
       # grubby --args="iommu=pt" --update-kernel DEFAULT
       ```

       NOTE

       The **pt** option only enables IOMMU for devices used in pass-through mode and provides better host performance. However, not all hardware supports the option. You can still assign devices even when this option is not enabled.

    2. Reboot the host.

  - On 64-bit ARM hosts, assigning GPUs to VMs is currently not supported.

Procedure

1. Prevent the driver from binding to the GPU.

   a. Identify the PCI bus address to which the GPU is attached.

   ```
   # lspci -Dnn | grep VGA
   0000:02:00.0 VGA compatible controller [0300]: NVIDIA Corporation GK106GL [Quadro
   K4000] [10de:11fa] (rev a1)
   ```

   b. Prevent the host's graphics driver from using the GPU. To do so, use the GPU PCI ID with the pci-stub driver.
   For example, the following command prevents the driver from binding to the GPU attached at the **10de:11fa** bus:

   ```
   # grubby --args="pci-stub.ids=10de:11fa" --update-kernel DEFAULT
   ```

   c. Reboot the host.

2. Optional: If certain GPU functions, such as audio, cannot be passed through to the VM due to support limitations, you can modify the driver bindings of the endpoints within an IOMMU group to pass through only the necessary GPU functions.

   a. Convert the GPU settings to XML and note the PCI address of the endpoints that you want to prevent from attaching to the host drivers.
   To do so, convert the GPU's PCI bus address to a libvirt-compatible format by adding the **pci_** prefix to the address, and converting the delimiters to underscores.

   For example, the following command displays the XML configuration of the GPU attached at the **0000:02:00.0** bus address.

   ```
   # virsh nodedev-dumpxml pci_0000_02_00_0
   ```

   ```
   <device>
    <name>pci_0000_02_00_0</name>
    <path>/sys/devices/pci0000:00/0000:00:03.0/0000:02:00.0</path>
    <parent>pci_0000_00_03_0</parent>
    <driver>
     <name>pci-stub</name>
    </driver>
    <capability type='pci'>
     <domain>0</domain>
     <bus>2</bus>
     <slot>0</slot>
     <function>0</function>
     <product id='0x11fa'>GK106GL [Quadro K4000]</product>
     <vendor id='0x10de'>NVIDIA Corporation</vendor>
     <iommuGroup number='13'>
      <address domain='0x0000' bus='0x02' slot='0x00' function='0x0'/>
      <address domain='0x0000' bus='0x02' slot='0x00' function='0x1'/>
     </iommuGroup>
   ```

```
  <pci-express>
   <link validity='cap' port='0' speed='8' width='16'/>
   <link validity='sta' speed='2.5' width='16'/>
  </pci-express>
 </capability>
</device>
```

b. Prevent the endpoints from attaching to the host driver.
In this example, to assign the GPU to a VM, prevent the endpoints that correspond to the audio function, **<address domain='0x0000' bus='0x02' slot='0x00' function='0x1'/>**, from attaching to the host audio driver, and instead attach the endpoints to VFIO-PCI.

```
# driverctl set-override 0000:02:00.1 vfio-pci
```

3. Attach the GPU to the VM

a. Create an XML configuration file for the GPU by using the PCI bus address.
For example, you can create the following XML file, GPU-Assign.xml, by using parameters from the GPU's bus address.

```
<hostdev mode='subsystem' type='pci' managed='yes'>
 <driver name='vfio'/>
 <source>
  <address domain='0x0000' bus='0x02' slot='0x00' function='0x0'/>
 </source>
</hostdev>
```

b. Save the file on the host system.

c. Merge the file with the VM's XML configuration.
For example, the following command merges the GPU XML file, GPU-Assign.xml, with the XML configuration file of the **System1** VM.

```
# virsh attach-device System1 --file /home/GPU-Assign.xml --persistent
Device attached successfully.
```

NOTE

The GPU is attached as a secondary graphics device to the VM. Assigning a GPU as the primary graphics device is not supported, and Red Hat does not recommend removing the primary emulated graphics device in the VM's XML configuration.

Verification

- The device appears under the **<devices>** section in VM's XML configuration. For more information, see Sample virtual machine XML configuration.

Known Issues

- Attaching an NVIDIA GPU device to a VM that uses a RHEL 9 guest operating system currently disables the Wayland session on that VM, and loads an Xorg session instead.

16.2. MANAGING NVIDIA VGPU DEVICES

The vGPU feature makes it possible to divide a physical NVIDIA GPU device into multiple virtual devices, referred to as **mediated devices**. These mediated devices can then be assigned to multiple virtual machines (VMs) as virtual GPUs. As a result, these VMs can share the performance of a single physical GPU.

IMPORTANT

Assigning a physical GPU to VMs, with or without using mediated devices, makes it impossible for the host to use the GPU.

16.2.1. Setting up NVIDIA vGPU devices

To set up the NVIDIA vGPU feature, you need to download NVIDIA vGPU drivers for your GPU device, create mediated devices, and assign them to the intended virtual machines. For detailed instructions, see below.

Prerequisites

- Your GPU supports vGPU mediated devices. For an up-to-date list of NVIDIA GPUs that support creating vGPUs, see the NVIDIA vGPU software documentation.
    - If you do not know which GPU your host is using, install the *lshw* package and use the **lshw -C display** command. The following example shows the system is using an NVIDIA Tesla P4 GPU, compatible with vGPU.

```
# lshw -C display

*-display
     description: 3D controller
     product: GP104GL [Tesla P4]
     vendor: NVIDIA Corporation
     physical id: 0
     bus info: pci@0000:01:00.0
     version: a1
     width: 64 bits
     clock: 33MHz
     capabilities: pm msi pciexpress cap_list
     configuration: driver=vfio-pci latency=0
     resources: irq:16 memory:f6000000-f6ffffff memory:e0000000-efffffff
memory:f0000000-f1ffffff
```

Procedure

1. Download the NVIDIA vGPU drivers and install them on your system. For instructions, see the NVIDIA documentation.

2. If the NVIDIA software installer did not create the **/etc/modprobe.d/nvidia-installer-disable-nouveau.conf** file, create a **conf** file of any name in **/etc/modprobe.d/**, and add the following lines in the file:

```
blacklist nouveau
options nouveau modeset=0
```

3. Regenerate the initial ramdisk for the current kernel, then reboot.

```
# dracut --force
# reboot
```

4. Check that the kernel has loaded the **nvidia_vgpu_vfio** module and that the **nvidia-vgpu-mgr.service** service is running.

```
# lsmod | grep nvidia_vgpu_vfio
nvidia_vgpu_vfio 45011 0
nvidia 14333621 10 nvidia_vgpu_vfio
mdev 20414 2 vfio_mdev,nvidia_vgpu_vfio
vfio 32695 3 vfio_mdev,nvidia_vgpu_vfio,vfio_iommu_type1

# systemctl status nvidia-vgpu-mgr.service
nvidia-vgpu-mgr.service - NVIDIA vGPU Manager Daemon
   Loaded: loaded (/usr/lib/systemd/system/nvidia-vgpu-mgr.service; enabled; vendor preset:
disabled)
   Active: active (running) since Fri 2018-03-16 10:17:36 CET; 5h 8min ago
 Main PID: 1553 (nvidia-vgpu-mgr)
 [...]
```

In addition, if creating vGPU based on an NVIDIA Ampere GPU device, ensure that virtual functions are enable for the physical GPU. For instructions, see the NVIDIA documentation.

5. Generate a device UUID.

```
# uuidgen
30820a6f-b1a5-4503-91ca-0c10ba58692a
```

6. Prepare an XML file with a configuration of the mediated device, based on the detected GPU hardware. For example, the following configures a mediated device of the **nvidia-63** vGPU type on an NVIDIA Tesla P4 card that runs on the 0000:01:00.0 PCI bus and uses the UUID generated in the previous step.

```
<device>
    <parent>pci_0000_01_00_0</parent>
    <capability type="mdev">
        <type id="nvidia-63"/>
        <uuid>30820a6f-b1a5-4503-91ca-0c10ba58692a</uuid>
    </capability>
</device>
```

7. Define a vGPU mediated device based on the XML file you prepared. For example:

```
# virsh nodedev-define vgpu-test.xml
Node device mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0 created
from vgpu-test.xml
```

8. Optional: Verify that the mediated device is listed as inactive.

```
# virsh nodedev-list --cap mdev --inactive
mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
```

9. Start the vGPU mediated device you created.

   ```
   # virsh nodedev-start mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
   Device mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0 started
   ```

10. Optional: Ensure that the mediated device is listed as active.

    ```
    # virsh nodedev-list --cap mdev
    mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
    ```

11. Set the vGPU device to start automatically after the host reboots

    ```
    # virsh nodedev-autostart
    mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
    Device mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0 marked as
    autostarted
    ```

12. Attach the mediated device to a VM that you want to share the vGPU resources. To do so, add the following lines, along with the previously genereated UUID, to the **<devices/>** sections in the XML configuration of the VM.

    - To attach a single vGPU to a VM:

      ```
      ...
      <video>
        <model type='none'/>
      </video>
      ...

      <hostdev mode='subsystem' type='mdev' managed='no' model='vfio-pci' display='on'
      ramfb="on">
        <source>
          <address uuid='30820a6f-b1a5-4503-91ca-0c10ba58692a'/>
        </source>
      </hostdev>
      ```

      Note that each UUID can only be assigned to one VM at a time.

    - To attach multiple vGPUs to a VM:

      ```
      ...
      <video>
        <model type='none'/>
      </video>
      ...

      <hostdev mode='subsystem' type='mdev' managed='no' model='vfio-pci' display='on'
      ramfb="on">
        <source>
          <address uuid='30820a6f-b1a5-4503-91ca-0c10ba58692a'/>
        </source>
      </hostdev>

      <hostdev mode='subsystem' type='mdev' managed='no' model='vfio-pci'>
        <source>
      ```

```
    <address uuid='751c2bd9-3322-4031-ad07-50a0d1367577'/>
  </source>
</hostdev>
```

13. For full functionality of the vGPU mediated devices to be available on the assigned VMs, set up NVIDIA vGPU guest software licensing on the VMs. For further information and instructions, see the NVIDIA Virtual GPU Software License Server User Guide .

Verification

1. Query the capabilities of the vGPU you created, and ensure it is listed as active and persistent.

```
# virsh nodedev-info mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
Name:           virsh nodedev-autostart
mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
Parent:         pci_0000_01_00_0
Active:         yes
Persistent:     yes
Autostart:      yes
```

2. Start the VM and verify that the guest operating system detects the mediated device as an NVIDIA GPU. For example, if the VM uses Linux:

```
# lspci -d 10de: -k
07:00.0 VGA compatible controller: NVIDIA Corporation GV100GL [Tesla V100 SXM2 32GB]
(rev a1)
        Subsystem: NVIDIA Corporation Device 12ce
        Kernel driver in use: nvidia
        Kernel modules: nouveau, nvidia_drm, nvidia
```

Known Issues

- Assigning an NVIDIA vGPU mediated device to a VM that uses a RHEL 9 guest operating system currently disables the Wayland session on that VM, and loads an Xorg session instead.

Additional resources

- NVIDIA vGPU software documentation
- The **man virsh** command

Additional resources

- NVIDIA vGPU for Compute documentation

16.2.2. Removing NVIDIA vGPU devices

To change the configuration of assigned vGPU mediated devices, you need to remove the existing devices from the assigned VMs. For instructions, see below:

Prerequisites

- The VM from which you want to remove the device is shut down.

Procedure

1. Obtain the ID of the mediated device that you want to remove.

   ```
   # virsh nodedev-list --cap mdev
   mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
   ```

2. Stop the running instance of the vGPU mediated device.

   ```
   # virsh nodedev-destroy mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
   Destroyed node device 'mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0'
   ```

3. Optional: Ensure the mediated device has been deactivated.

   ```
   # virsh nodedev-info mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
   Name:           virsh nodedev-autostart
   mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
   Parent:         pci_0000_01_00_0
   Active:         no
   Persistent:     yes
   Autostart:      yes
   ```

4. Remove the device from the XML configuration of the VM. To do so, use the **virsh edit** utility to edit the XML configuration of the VM, and remove the mdev's configuration segment. The segment will look similar to the following:

   ```
   <hostdev mode='subsystem' type='mdev' managed='no' model='vfio-pci'>
     <source>
       <address uuid='30820a6f-b1a5-4503-91ca-0c10ba58692a'/>
     </source>
   </hostdev>
   ```

   Note that stopping and detaching the mediated device does not delete it, but rather keeps it as **defined**. As such, you can restart and attach the device to a different VM.

5. Optional: To delete the stopped mediated device, remove its definition.

   ```
   # virsh nodedev-undefine
   mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
   Undefined node device 'mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0'
   ```

Verification

- If you only stopped and detached the device, ensure the mediated device is listed as inactive.

  ```
  # virsh nodedev-list --cap mdev --inactive
  mdev_30820a6f_b1a5_4503_91ca_0c10ba58692a_0000_01_00_0
  ```

- If you also deleted the device, ensure the following command does not display it.

  ```
  # virsh nodedev-list --cap mdev
  ```

Additional resources

Additional resources

- The **man virsh** command

16.2.3. Obtaining NVIDIA vGPU information about your system

To evaluate the capabilities of the vGPU features available to you, you can obtain additional information about the mediated devices on your system, such as:

- How many mediated devices of a given type can be created
- What mediated devices are already configured on your system.

Procedure

- To see the available GPUs devices on your host that can support vGPU mediated devices, use the **virsh nodedev-list --cap mdev_types** command. For example, the following shows a system with two NVIDIA Quadro RTX6000 devices.

```
# virsh nodedev-list --cap mdev_types
pci_0000_5b_00_0
pci_0000_9b_00_0
```

- To display vGPU types supported by a specific GPU device, as well as additional metadata, use the **virsh nodedev-dumpxml** command.

```
# virsh nodedev-dumpxml pci_0000_9b_00_0
<device>
  <name>pci_0000_9b_00_0</name>
  <path>/sys/devices/pci0000:9a/0000:9a:00.0/0000:9b:00.0</path>
  <parent>pci_0000_9a_00_0</parent>
  <driver>
    <name>nvidia</name>
  </driver>
  <capability type='pci'>
    <class>0x030000</class>
    <domain>0</domain>
    <bus>155</bus>
    <slot>0</slot>
    <function>0</function>
    <product id='0x1e30'>TU102GL [Quadro RTX 6000/8000]</product>
    <vendor id='0x10de'>NVIDIA Corporation</vendor>
    <capability type='mdev_types'>
      <type id='nvidia-346'>
        <name>GRID RTX6000-12C</name>
        <deviceAPI>vfio-pci</deviceAPI>
        <availableInstances>2</availableInstances>
      </type>
      <type id='nvidia-439'>
        <name>GRID RTX6000-3A</name>
        <deviceAPI>vfio-pci</deviceAPI>
        <availableInstances>8</availableInstances>
      </type>
      [...]
      <type id='nvidia-440'>
        <name>GRID RTX6000-4A</name>
        <deviceAPI>vfio-pci</deviceAPI>
        <availableInstances>6</availableInstances>
      </type>
      <type id='nvidia-261'>
        <name>GRID RTX6000-8Q</name>
        <deviceAPI>vfio-pci</deviceAPI>
        <availableInstances>3</availableInstances>
      </type>
    </capability>
    <iommuGroup number='216'>
      <address domain='0x0000' bus='0x9b' slot='0x00' function='0x3'/>
      <address domain='0x0000' bus='0x9b' slot='0x00' function='0x1'/>
      <address domain='0x0000' bus='0x9b' slot='0x00' function='0x2'/>
      <address domain='0x0000' bus='0x9b' slot='0x00' function='0x0'/>
    </iommuGroup>
    <numa node='2'/>
    <pci-express>
      <link validity='cap' port='0' speed='8' width='16'/>
      <link validity='sta' speed='2.5' width='8'/>
    </pci-express>
  </capability>
</device>
```

Additional resources

- The **man virsh** command

16.2.4. Remote desktop streaming services for NVIDIA vGPU

The following remote desktop streaming services are supported on the RHEL 9 hypervisor with NVIDIA vGPU or NVIDIA GPU passthrough enabled:

- **HP ZCentral Remote Boost/Teradici**
- **NICE DCV**
- **Mechdyne TGX**

For support details, see the appropriate vendor support matrix.

16.2.5. Additional resources

- NVIDIA vGPU software documentation

CHAPTER 17. CONFIGURING VIRTUAL MACHINE NETWORK CONNECTIONS

For your virtual machines (VMs) to connect over a network to your host, to other VMs on your host, and to locations on an external network, the VM networking must be configured accordingly. To provide VM networking, the RHEL 9 hypervisor and newly created VMs have a default network configuration, which can also be modified further. For example:

- You can enable the VMs on your host to be discovered and connected to by locations outside the host, as if the VMs were on the same network as the host.
- You can partially or completely isolate a VM from inbound network traffic to increase its security and minimize the risk of any problems with the VM impacting the host.

The following sections explain the various types of VM network configuration and provide instructions for setting up selected VM network configurations.

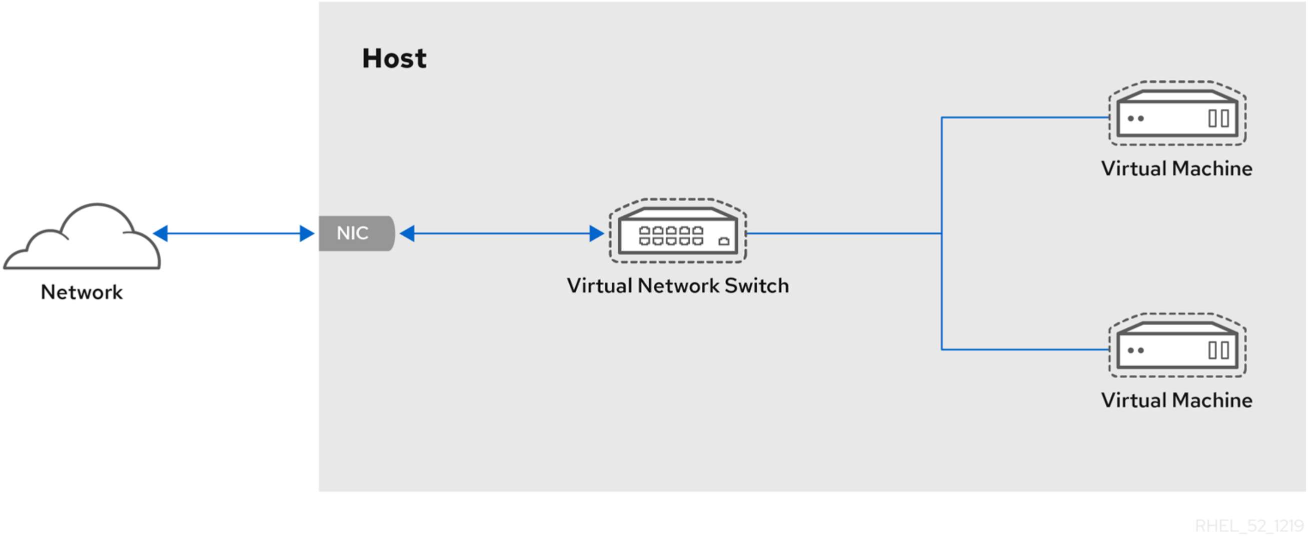
17.1. UNDERSTANDING VIRTUAL NETWORKING

The connection of virtual machines (VMs) to other devices and locations on a network has to be facilitated by the host hardware. The following sections explain the mechanisms of VM network connections and describe the default VM network setting.

17.1.1. How virtual networks work

Virtual networking uses the concept of a virtual network switch. A virtual network switch is a software construct that operates on a host machine. VMs connect to the network through the virtual network switch. Based on the configuration of the virtual switch, a VM can use an existing virtual network managed by the hypervisor, or a different network connection method.

The following figure shows a virtual network switch connecting two VMs to the network:



From the perspective of a guest operating system, a virtual network connection is the same as a physical network connection. Host machines view virtual network switches as network interfaces. When the **virtnetworkd** service is first installed and started, it creates virbr0, the default network interface for VMs.

To view information about this interface, use the **ip** utility on the host.

```
$ ip addr show virbr0
3: virbr0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state
UNKNOWN link/ether 1b:c4:94:cf:fd:17 brd ff:ff:ff:ff:ff:ff
inet 192.0.2.1/24 brd 192.0.2.255 scope global virbr0
```

By default, all VMs on a single host are connected to the same NAT-type virtual network, named **default**, which uses the **virbr0** interface. For details, see Virtual networking default configuration .

For basic outbound-only network access from VMs, no additional network setup is usually needed, because the default network is installed along with the **libvirt-daemon-config-network** package, and is automatically started when the **virtnetworkd** service is started.

If a different VM network functionality is needed, you can create additional virtual networks and network interfaces and configure your VMs to use them. In addition to the default NAT, these networks and interfaces can be configured to use one of the following modes:

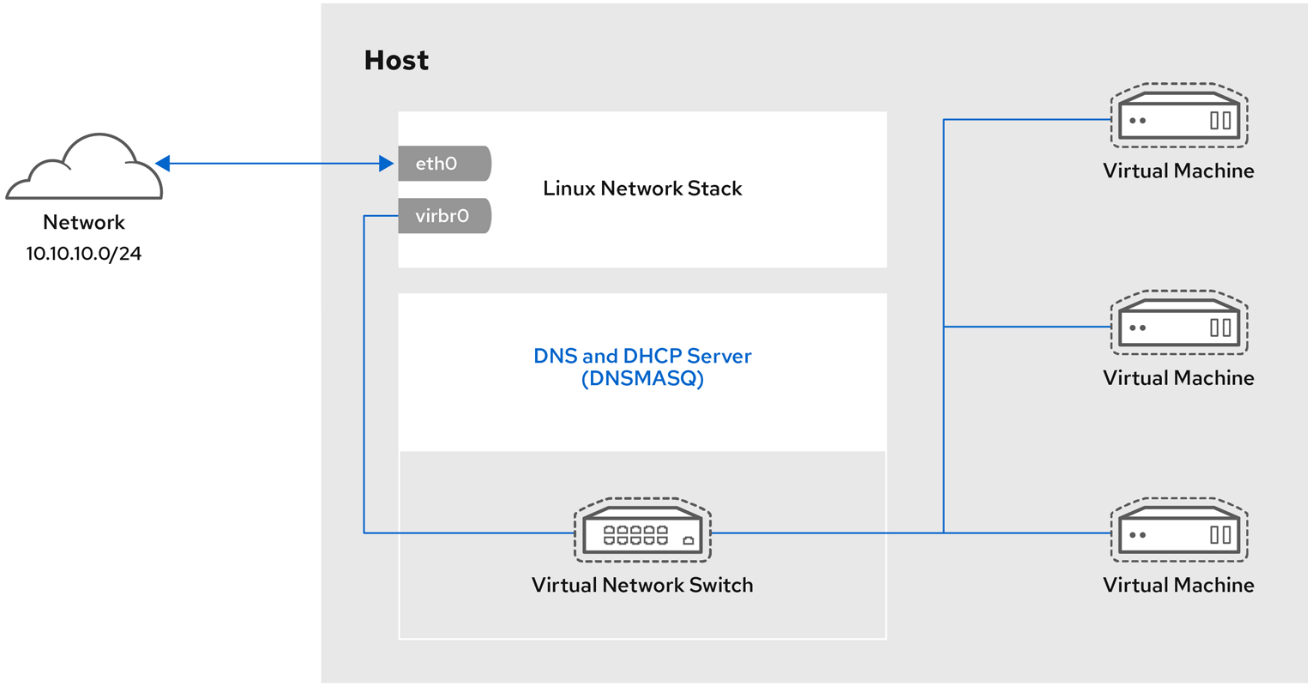
- Routed mode
- Bridged mode
- Isolated mode
- Open mode

17.1.2. Virtual networking default configuration

When the **virtnetworkd** service is first installed on a virtualization host, it contains an initial virtual network configuration in network address translation (NAT) mode. By default, all VMs on the host are connected to the same **libvirt** virtual network, named **default**. VMs on this network can connect to locations both on the host and on the network beyond the host, but with the following limitations:

- VMs on the network are visible to the host and other VMs on the host, but the network traffic is affected by the firewalls in the guest operating system's network stack and by the **libvirt** network filtering rules attached to the guest interface.
- VMs on the network can connect to locations outside the host but are not visible to them. Outbound traffic is affected by the NAT rules, as well as the host system's firewall.

The following diagram illustrates the default VM network configuration:



RHEL_52_1219

17.2. USING THE WEB CONSOLE FOR MANAGING VIRTUAL MACHINE NETWORK INTERFACES

Using the RHEL 9 web console, you can manage the virtual network interfaces for the virtual machines to which the web console is connected. You can:

- View information about network interfaces and edit them .
- Add network interfaces to virtual machines , and disconnect or delete the interfaces.

17.2.1. Viewing and editing virtual network interface information in the web console

By using the RHEL 9 web console, you can view and modify the virtual network interfaces on a selected virtual machine (VM):

Prerequisites

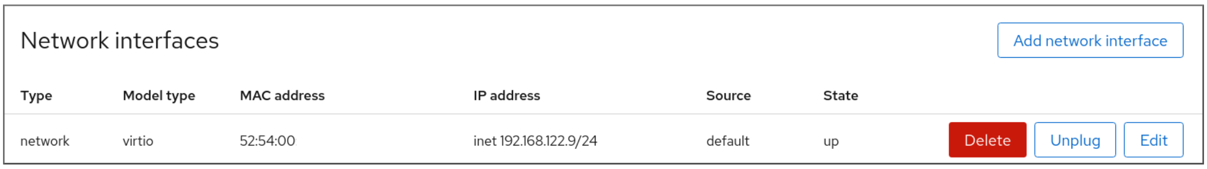
- You have installed the RHEL 9 web console.
- You have enabled the cockpit service.
- Your user account is allowed to log in to the web console.
  For instructions, see Installing and enabling the web console .
- The web console VM plug-in is installed on your system.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .
2. In the **Virtual Machines** interface, click the VM whose information you want to see.

A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

3. Scroll to **Network Interfaces**.
   The Networks Interfaces section displays information about the virtual network interface configured for the VM as well as options to **Add**, **Delete**, **Edit**, or **Unplug** network interfaces.



Network interfaces

Type	Model type	MAC address	IP address	Source	State
network	virtio	52:54:00	inet 192.168.122.9/24	default	up

The information include the following:

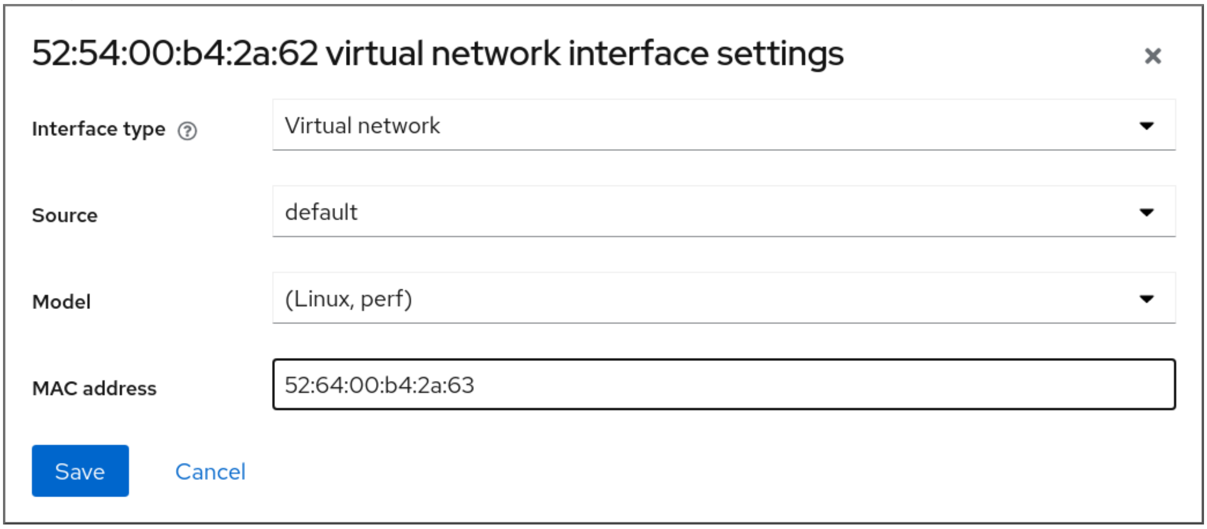
- **Type** - The type of network interface for the VM. The types include virtual network, bridge to LAN, and direct attachment.

NOTE

Generic Ethernet connection is not supported in RHEL 9 and later.

- **Model type** - The model of the virtual network interface.
- **MAC Address** - The MAC address of the virtual network interface.
- **IP Address** - The IP address of the virtual network interface.
- **Source** - The source of the network interface. This is dependent on the network type.
- **State** - The state of the virtual network interface.

4. To edit the virtual network interface settings, Click **Edit**. The Virtual Network Interface Settings dialog opens.



52:54:00:b4:2a:62 virtual network interface settings

Interface type: Virtual network

Source: default

Model: (Linux, perf)

MAC address: 52:64:00:b4:2a:63

5. Change the interface type, source, model, or MAC address.

6. Click **Save**. The network interface is modified.

NOTE

Changes to the virtual network interface settings take effect only after restarting the VM.

Additionally, MAC address can only be modified when the VM is shut off.

Additional resources

- Viewing virtual machine information by using the web console

17.2.2. Adding and connecting virtual network interfaces in the web console

By using the RHEL 9 web console, you can create a virtual network interface and connect a virtual machine (VM) to it.

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 web console VM plug-in 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 **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.
3. Scroll to **Network Interfaces**.
   The Networks Interfaces section displays information about the virtual network interface configured for the VM as well as options to **Add**, **Edit**, or **Plug** network interfaces.
4. Click **Plug** in the row of the virtual network interface you want to connect.
   The selected virtual network interface connects to the VM.

17.2.3. Disconnecting and removing virtual network interfaces in the web console

By using the RHEL 9 web console, you can disconnect the virtual network interfaces connected to a selected virtual machine (VM).

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 .

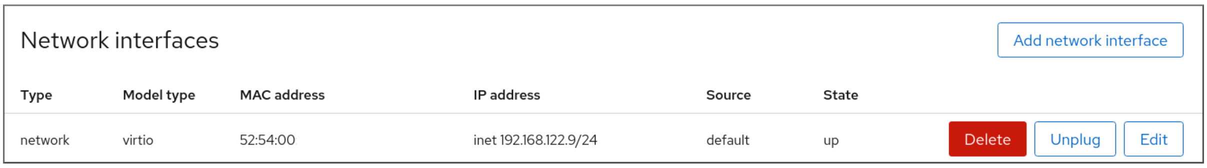
- The web console VM plug-in is installed on your system.

Procedure

1. Log in to the RHEL 9 web console.
   For details, see Logging in to the web console .

2. In the **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

3. Scroll to **Network Interfaces**.
   The Networks Interfaces section displays information about the virtual network interface configured for the VM as well as options to **Add**, **Delete**, **Edit**, or **Unplug** network interfaces.



Network interfaces

Type	Model type	MAC address	IP address	Source	State
network	virtio	52:54:00	inet 192.168.122.9/24	default	up

4. Click **Unplug** in the row of the virtual network interface you want to disconnect.
   The selected virtual network interface disconnects from the VM.

17.3. RECOMMENDED VIRTUAL MACHINE NETWORKING CONFIGURATIONS

In many scenarios, the default VM networking configuration is sufficient. However, if adjusting the configuration is required, you can use the command line (CLI) or the RHEL 9 web console to do so. The following sections describe selected VM network setups for such situations.

17.3.1. Configuring externally visible virtual machines by using the command line

By default, a newly created VM connects to a NAT-type network that uses **virbr0**, the default virtual bridge on the host. This ensures that the VM can use the host's network interface controller (NIC) for connecting to outside networks, but the VM is not reachable from external systems.

If you require a VM to appear on the same external network as the hypervisor, you must use bridged mode instead. To do so, attach the VM to a bridge device connected to the hypervisor's physical network device. To use the command line for this, follow the instructions below.

Prerequisites

- A shut-down existing VM with the default NAT setup.

- The IP configuration of the hypervisor. This varies depending on the network connection of the host. As an example, this procedure uses a scenario where the host is connected to the network by using an ethernet cable, and the hosts' physical NIC MAC address is assigned to a static IP on a DHCP server. Therefore, the ethernet interface is treated as the hypervisor IP.
  To obtain the IP configuration of the ethernet interface, use the **ip addr** utility:

```
# ip addr
[...]
```

```
enp0s25: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP
group default qlen 1000
    link/ether 54:ee:75:49:dc:46 brd ff:ff:ff:ff:ff:ff
    inet 192.0.2.1/24 brd 192.0.2.255 scope global dynamic noprefixroute enp0s25
```

Procedure

1. Create and set up a bridge connection for the physical interface on the host. For instructions, see the Configuring a network bridge .
   Note that in a scenario where static IP assignment is used, you must move the IPv4 setting of the physical ethernet interface to the bridge interface.

2. Modify the VM's network to use the created bridged interface. For example, the following sets *testguest* to use *bridge0*.

   ```
   # virt-xml testguest --edit --network bridge=bridge0
   Domain 'testguest' defined successfully.
   ```

3. Start the VM.

   ```
   # virsh start testguest
   ```

4. In the guest operating system, adjust the IP and DHCP settings of the system's network interface as if the VM was another physical system in the same network as the hypervisor.
   The specific steps for this will differ depending on the guest OS used by the VM. For example, if the guest OS is RHEL 9, see Configuring an Ethernet connection.

Verification

1. Ensure the newly created bridge is running and contains both the host's physical interface and the interface of the VM.

   ```
   # ip link show master bridge0
   2: enp0s25: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
   bridge0 state UP mode DEFAULT group default qlen 1000
       link/ether 54:ee:75:49:dc:46 brd ff:ff:ff:ff:ff:ff
   10: vnet0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel master
   bridge0 state UNKNOWN mode DEFAULT group default qlen 1000
       link/ether fe:54:00:89:15:40 brd ff:ff:ff:ff:ff:ff
   ```

2. Ensure the VM appears on the same external network as the hypervisor:

   a. In the guest operating system, obtain the network ID of the system. For example, if it is a Linux guest:

      ```
      # ip addr
      [...]
      enp0s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state
      UP group default qlen 1000
          link/ether 52:54:00:09:15:46 brd ff:ff:ff:ff:ff:ff
          inet 192.0.2.1/24 brd 192.0.2.255 scope global dynamic noprefixroute enp0s0
      ```

   b. From an external system connected to the local network, connect to the VM by using the obtained ID.

```
# ssh root@192.0.2.1
root@192.0.2.1's password:
Last login: Mon Sep 24 12:05:36 2019
root~#*
```

If the connection works, the network has been configured successfully.

Troubleshooting

- In certain situations, such as when using a client-to-site VPN while the VM is hosted on the client, using bridged mode for making your VMs available to external locations is not possible.
  To work around this problem, you can set destination NAT by using **nftables** for the VM.

Additional resources

- Configuring externally visible virtual machines by using the web console
- Virtual networking in bridged mode

17.3.2. Configuring externally visible virtual machines by using the web console

By default, a newly created VM connects to a NAT-type network that uses **virbr0**, the default virtual bridge on the host. This ensures that the VM can use the host's network interface controller (NIC) for connecting to outside networks, but the VM is not reachable from external systems.

If you require a VM to appear on the same external network as the hypervisor, you must use bridged mode instead. To do so, attach the VM to a bridge device connected to the hypervisor's physical network device. To use the RHEL 9 web console for this, follow the instructions below.

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 web console VM plug-in is installed on your system.
- A shut-down existing VM with the default NAT setup.
- The IP configuration of the hypervisor. This varies depending on the network connection of the host. As an example, this procedure uses a scenario where the host is connected to the network by using an ethernet cable, and the hosts' physical NIC MAC address is assigned to a static IP on a DHCP server. Therefore, the ethernet interface is treated as the hypervisor IP.
  To obtain the IP configuration of the ethernet interface, go to the **Networking** tab in the web console, and see the **Interfaces** section.

Procedure

1. Create and set up a bridge connection for the physical interface on the host. For instructions, see Configuring network bridges in the web console .

Note that in a scenario where static IP assignment is used, you must move the IPv4 setting of the physical ethernet interface to the bridge interface.

2. Modify the VM's network to use the bridged interface. In the Network Interfaces tab of the VM:

    a. Click **Add Network Interface**

    b. In the **Add Virtual Network Interface** dialog, set:

        - **Interface Type** to **Bridge to LAN**

        - Source to the newly created bridge, for example **bridge0**

    c. Click **Add**

    d. Optional: Click **Unplug** for all the other interfaces connected to the VM.

3. Click **Run** to start the VM.

4. In the guest operating system, adjust the IP and DHCP settings of the system's network interface as if the VM was another physical system in the same network as the hypervisor. The specific steps for this will differ depending on the guest OS used by the VM. For example, if the guest OS is RHEL 9, see Configuring an Ethernet connection.

Verification

1. In the **Networking** tab of the host's web console, click the row with the newly created bridge to ensure it is running and contains both the host's physical interface and the interface of the VM.

2. Ensure the VM appears on the same external network as the hypervisor.

    a. In the guest operating system, obtain the network ID of the system. For example, if it is a Linux guest:

    ```
    # ip addr
    [...]
    enp0s0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state
    UP group default qlen 1000
        link/ether 52:54:00:09:15:46 brd ff:ff:ff:ff:ff:ff
        inet 192.0.2.1/24 brd 192.0.2.255 scope global dynamic noprefixroute enp0s0
    ```

    b. From an external system connected to the local network, connect to the VM by using the obtained ID.

    ```
    # ssh root@192.0.2.1
    root@192.0.2.1's password:
    Last login: Mon Sep 24 12:05:36 2019
    root~#*
    ```

    If the connection works, the network has been configured successfully.

Troubleshooting

- In certain situations, such as when using a client-to-site VPN while the VM is hosted on the client, using bridged mode for making your VMs available to external locations is not possible.

Additional resources

- Configuring externally visible virtual machines by using the command line
- Virtual networking in bridged mode

17.3.3. Replacing macvtap connections

macvtap is a Linux networking device driver that creates a virtual network interface, through which virtual machines have direct access to the physical network interface on the host machine. Using **macvtap** connections is supported in RHEL 9.

However, in comparison to other available virtual machine (VM) networking configurations, macvtap has suboptimal performance and is more difficult to set up correctly. Therefore, if your use case does not explicitly require macvtap, use a different supported networking configuration.

If you are using a macvtap mode in your VM, consider instead using the following network configurations:

- Instead of macvtap bridge mode, use the Linux bridge configuration.
- Instead of macvtap passthrough mode, use PCI Passthrough.

Additional resources

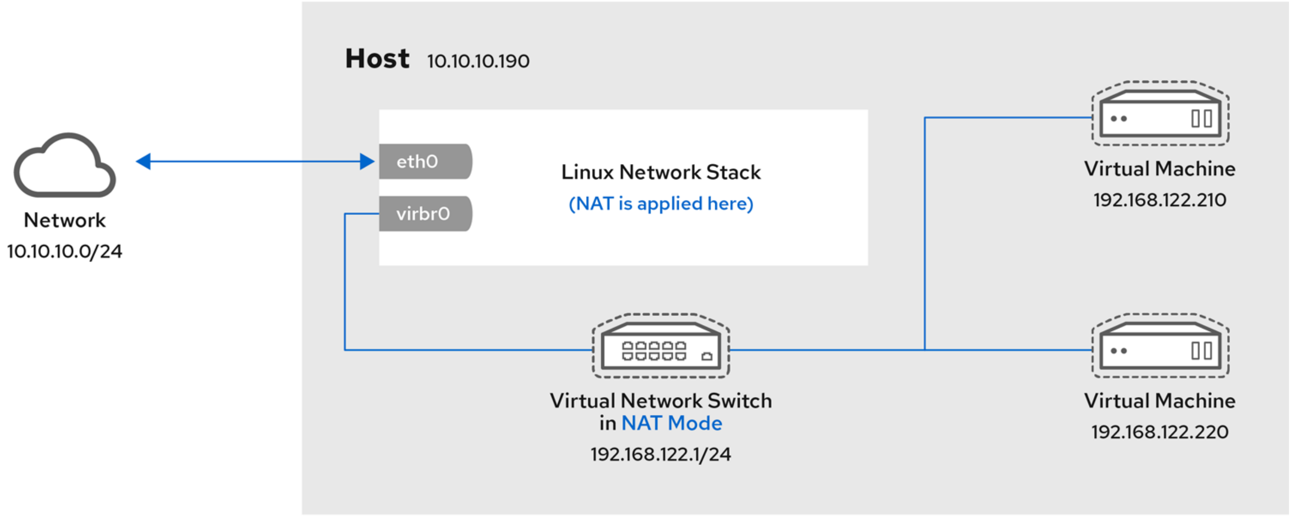
- Upstream documentation for macvtap

17.4. TYPES OF VIRTUAL MACHINE NETWORK CONNECTIONS

To modify the networking properties and behavior of your VMs, change the type of virtual network or interface the VMs use. The following sections describe the connection types available to VMs in RHEL 9.

17.4.1. Virtual networking with network address translation

By default, virtual network switches operate in network address translation (NAT) mode. They use IP masquerading rather than Source-NAT (SNAT) or Destination-NAT (DNAT). IP masquerading enables connected VMs to use the host machine's IP address for communication with any external network. When the virtual network switch is operating in NAT mode, computers external to the host cannot communicate with the VMs inside the host.



RHEL_52_1219

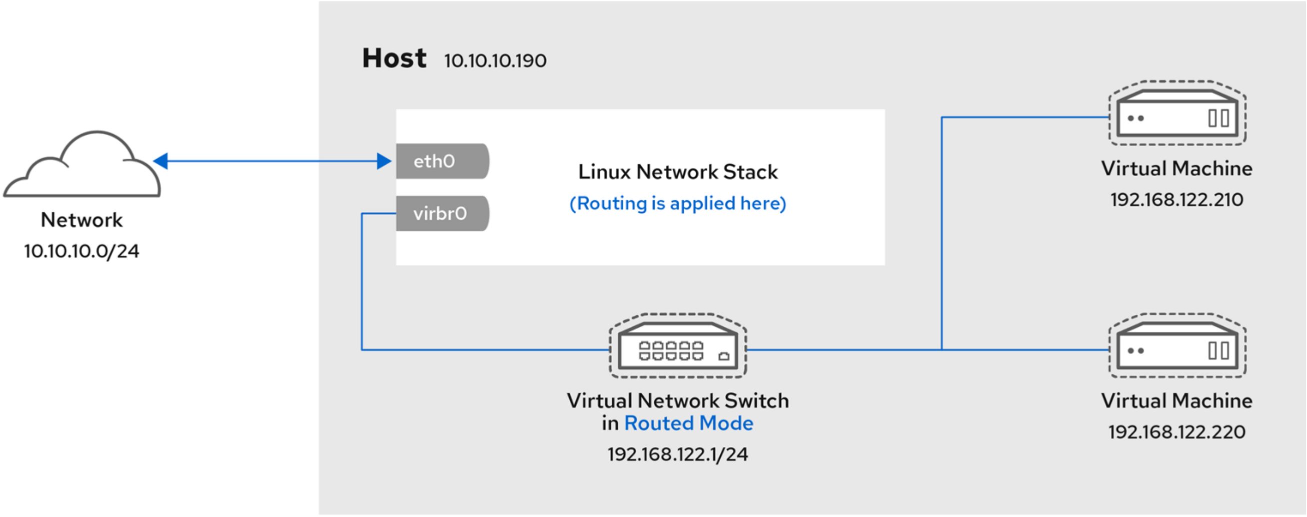
WARNING

Virtual network switches use NAT configured by firewall rules. Editing these rules while the switch is running is not recommended, because incorrect rules may result in the switch being unable to communicate.

17.4.2. Virtual networking in routed mode

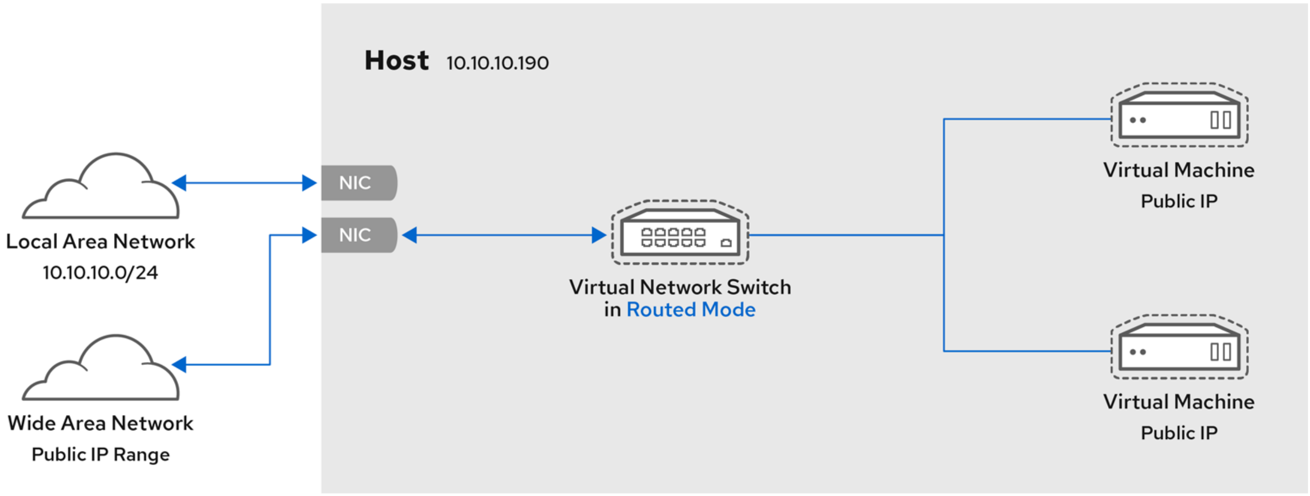
When using *Routed* mode, the virtual switch connects to the physical LAN connected to the host machine, passing traffic back and forth without the use of NAT. The virtual switch can examine all traffic and use the information contained within the network packets to make routing decisions. When using this mode, the virtual machines (VMs) are all in a single subnet, separate from the host machine. The VM subnet is routed through a virtual switch, which exists on the host machine. This enables incoming connections, but requires extra routing-table entries for systems on the external network.

Routed mode uses routing based on the IP address:



RHEL_52_1219

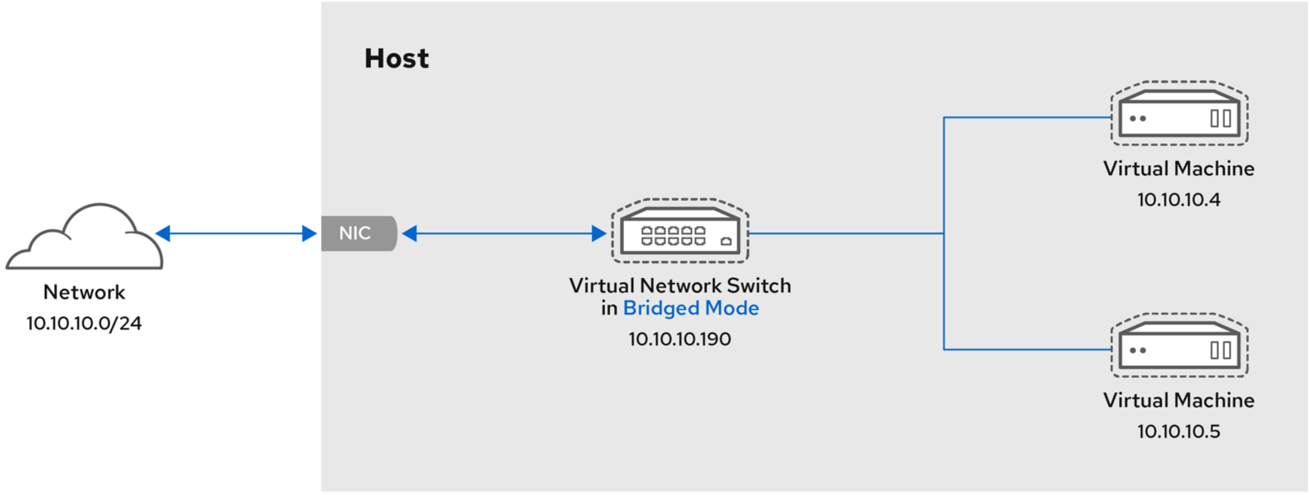
A common topology that uses routed mode is virtual server hosting (VSH). A VSH provider may have several host machines, each with two physical network connections. One interface is used for management and accounting, the other for the VMs to connect through. Each VM has its own public IP address, but the host machines use private IP addresses so that only internal administrators can manage the VMs.



17.4.3. Virtual networking in bridged mode

In most VM networking modes, VMs automatically create and connect to the **virbr0** virtual bridge. In contrast, in *bridged* mode, the VM connects to an existing Linux bridge on the host. As a result, the VM is directly visible on the physical network. This enables incoming connections, but does not require any extra routing-table entries.

Bridged mode uses connection switching based on the MAC address:



In bridged mode, the VM appear within the same subnet as the host machine. All other physical machines on the same physical network can detect the VM and access it.

Bridged network bonding

It is possible to use multiple physical bridge interfaces on the hypervisor by joining them together with a bond. The bond can then be added to a bridge, after which the VMs can be added to the bridge as well. However, the bonding driver has several modes of operation, and not all of these modes work with a bridge where VMs are in use.

The following bonding modes are usable:

- mode 1

- mode 2
- mode 4

In contrast, modes 0, 3, 5, or 6 is likely to cause the connection to fail. Also note that media-independent interface (MII) monitoring should be used to monitor bonding modes, as Address Resolution Protocol (ARP) monitoring does not work correctly.

For more information about bonding modes, see the Red Hat Knowledgebase solution Which bonding modes work when used with a bridge that virtual machine guests or containers connect to?.

Common scenarios

The most common use cases for bridged mode include:

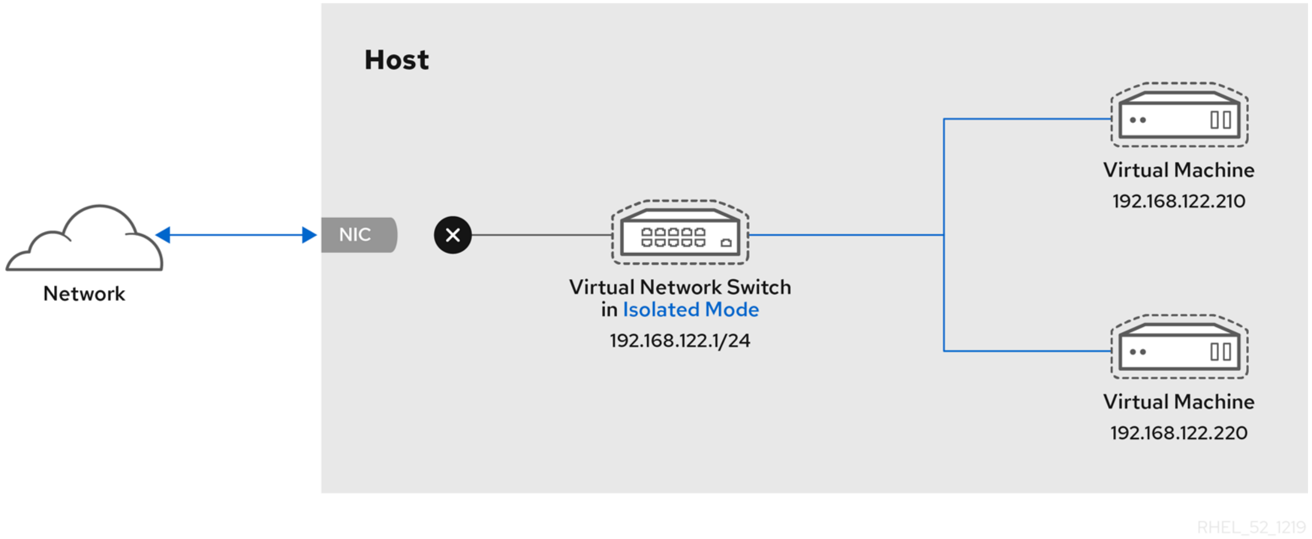
- Deploying VMs in an existing network alongside host machines, making the difference between virtual and physical machines invisible to the end user.
- Deploying VMs without making any changes to existing physical network configuration settings.
- Deploying VMs that must be easily accessible to an existing physical network. Placing VMs on a physical network where they must access DHCP services.
- Connecting VMs to an existing network where virtual LANs (VLANs) are used.
- A demilitarized zone (DMZ) network. For a DMZ deployment with VMs, Red Hat recommends setting up the DMZ at the physical network router and switches, and connecting the VMs to the physical network by using bridged mode.

Additional resources

- Configuring externally visible virtual machines by using the command line
- Configuring externally visible virtual machines by using the web console
- Explanation of **bridge_opts** parameters

17.4.4. Virtual networking in isolated mode

By using *isolated* mode, virtual machines connected to the virtual switch can communicate with each other and with the host machine, but their traffic will not pass outside of the host machine, and they cannot receive traffic from outside the host machine. Using **dnsmasq** in this mode is required for basic functionality such as DHCP.



17.4.5. Virtual networking in open mode

When using *open* mode for networking, **libvirt** does not generate any firewall rules for the network. As a result, **libvirt** does not overwrite firewall rules provided by the host, and the user can therefore manually manage the VM’s firewall rules.

17.4.6. Comparison of virtual machine connection types

The following table provides information about the locations to which selected types of virtual machine (VM) network configurations can connect, and to which they are visible.

Table 17.1. Virtual machine connection types

	Connection to the host	Connection to other VMs on the host	Connection to outside locations	Visible to outside locations
Bridged mode	YES	YES	YES	YES
NAT	YES	YES	YES	*no*
Routed mode	YES	YES	YES	YES
Isolated mode	YES	YES	*no*	*no*
Open mode	*Depends on the host’s firewall rules*			

17.5. BOOTING VIRTUAL MACHINES FROM A PXE SERVER

Virtual machines (VMs) that use Preboot Execution Environment (PXE) can boot and load their configuration from a network. This chapter describes how to use **libvirt** to boot VMs from a PXE server on a virtual or bridged network.

WARNING

These procedures are provided only as an example. Ensure that you have sufficient backups before proceeding.

17.5.1. Setting up a PXE boot server on a virtual network

This procedure describes how to configure a **libvirt** virtual network to provide Preboot Execution Environment (PXE). This enables virtual machines on your host to be configured to boot from a boot image available on the virtual network.

Prerequisites

- A local PXE server (DHCP and TFTP), such as:
  - libvirt internal server
  - manually configured dhcpd and tftpd
  - dnsmasq
  - Cobbler server
- PXE boot images, such as **PXELINUX** configured by Cobbler or manually.

Procedure

1. Place the PXE boot images and configuration in **/var/lib/tftpboot** folder.
2. Set folder permissions:

```
# chmod -R a+r /var/lib/tftpboot
```

3. Set folder ownership:

```
# chown -R nobody: /var/lib/tftpboot
```

4. Update SELinux context:

```
# chcon -R --reference /usr/sbin/dnsmasq /var/lib/tftpboot
# chcon -R --reference /usr/libexec/libvirt_leaseshelper /var/lib/tftpboot
```

5. Shut down the virtual network:

```
# virsh net-destroy default
```

6. Open the virtual network configuration file in your default editor:

```
# virsh net-edit default
```

7. Edit the **<ip>** element to include the appropriate address, network mask, DHCP address range, and boot file, where *example-pxelinux* is the name of the boot image file.

```
<ip address='192.0.2.1' netmask='255.255.255.0'>
  <tftp root='/var/lib/tftpboot'/>
  <dhcp>
    <range start='192.0.2.2' end='192.0.2.254' />
    <bootp file='example-pxelinux'/>
  </dhcp>
</ip>
```

8. Start the virtual network:

```
# virsh net-start default
```

Verification

- Verify that the **default** virtual network is active:

```
# virsh net-list
Name             State    Autostart   Persistent
---------------------------------------------------
default          active   no          no
```

Additional resources

- Preparing a PXE installation source

17.5.2. Booting virtual machines by using PXE and a virtual network

To boot virtual machines (VMs) from a Preboot Execution Environment (PXE) server available on a virtual network, you must enable PXE booting.

Prerequisites

- A PXE boot server is set up on the virtual network as described in Setting up a PXE boot server on a virtual network.

Procedure

- Create a new VM with PXE booting enabled. For example, to install from a PXE, available on the **default** virtual network, into a new 10 GB qcow2 image file:

```
# virt-install --pxe --network network=default --memory 2048 --vcpus 2 --disk size=10
```

  - Alternatively, you can manually edit the XML configuration file of an existing VM. To do so, ensure the guest network is configured to use your virtual network and that the network is configured to be the primary boot device:

```
<interface type='network'>
  <mac address='52:54:00:66:79:14'/>
  <source network='default'/>
  <target dev='vnet0'/>
  <alias name='net0'/>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x03' function='0x0'/>
  <boot order='1'/>
</interface>
```

Verification

- Start the VM by using the **virsh start** command. If PXE is configured correctly, the VM boots from a boot image available on the PXE server.

17.5.3. Booting virtual machines by using PXE and a bridged network

To boot virtual machines (VMs) from a Preboot Execution Environment (PXE) server available on a bridged network, you must enable PXE booting.

Prerequisites

- Network bridging is enabled.
- A PXE boot server is available on the bridged network.

Procedure

- Create a new VM with PXE booting enabled. For example, to install from a PXE, available on the **breth0** bridged network, into a new 10 GB qcow2 image file:

  ```
  # virt-install --pxe --network bridge=breth0 --memory 2048 --vcpus 2 --disk size=10
  ```

  - Alternatively, you can manually edit the XML configuration file of an existing VM. To do so, ensure that the VM is configured with a bridged network and that the network is configured to be the primary boot device:

    ```
    <interface type='bridge'>
      <mac address='52:54:00:5a:ad:cb'/>
      <source bridge='breth0'/>
      <target dev='vnet0'/>
      <alias name='net0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x03' function='0x0'/>
      <boot order='1'/>
    </interface>
    ```

Verification

- Start the VM by using the **virsh start** command. If PXE is configured correctly, the VM boots from a boot image available on the PXE server.

Additional resources

- Configuring a network bridge

17.6. CONFIGURING BRIDGES ON A NETWORK BOND TO CONNECT VIRTUAL MACHINES WITH THE NETWORK

The network bridge connects VMs with the same network as the host. If you want to connect VMs on one host to another host or VMs on another host, a bridge establishes communication between them. However, the bridge does not provide a fail-over mechanism. To handle failures in communication, a network bond handles communication in the event of failure of a network interface. To maintain fault tolerance and redundancy, the **active-backup** bonding mechanism determines that only one port is active in the bond and does not require any switch configuration. If an active port fails, an alternate port becomes active to retain communication between configured VMs in the network.

17.6.1. Configuring network interfaces on a network bond by using nmcli

To configure a network bond on the command line, use the **nmcli** utility.

Prerequisites

- Two or more physical devices are installed on the server, and they are not configured in any **NetworkManager** connection profile.

Procedure

1. Create a bond interface:

   ```
   # nmcli connection add type bond con-name bond0 ifname bond0 bond.options
   "mode=active-backup"
   ```

   This command creates a bond named **bond0** that uses the **active-backup** mode.

2. Assign the Ethernet interfaces to the bond:

   ```
   # nmcli connection add type ethernet slave-type bond con-name bond0-port1 ifname
   enp7s0 master bond0
   # nmcli connection add type ethernet slave-type bond con-name bond0-port2 ifname
   enp8s0 master bond0
   ```

   These commands create profiles for **enp7s0** and **enp8s0**, and add them to the **bond0** connection.

3. Configure the IPv4 settings:

   - To use DHCP, no action is required.
   - To set a static IPv4 address, network mask, default gateway, and DNS server to the **bond0** connection, enter:

     ```
     # nmcli connection modify bond0 ipv4.addresses 192.0.2.1/24 ipv4.gateway
     192.0.2.254 ipv4.dns 192.0.2.253 ipv4.dns-search example.com ipv4.method
     manual
     ```

4. Configure the IPv6 settings:

   - To use stateless address autoconfiguration (SLAAC), no action is required.
   - To set a static IPv6 address, network mask, default gateway, and DNS server to the **bond0** connection, enter:

     ```
     # nmcli connection modify bond0 ipv6.addresses 2001:db8:1::1/64 ipv6.gateway
     ```

```
2001:db8:1::fffe ipv6.dns 2001:db8:1::fffd ipv6.dns-search example.com
ipv6.method manual
```

5. Optional: If you want to set any parameters on the bond ports, use the following command:

   ```
   # nmcli connection modify bond0-port1 bond-port.<parameter> <value>
   ```

6. Configure that Red Hat Enterprise Linux enables all ports automatically when the bond is enabled:

   ```
   # nmcli connection modify bond0 connection.autoconnect-ports 1
   ```

7. Activate the bridge:

   ```
   # nmcli connection up bond0
   ```

Verification

1. Temporarily remove the network cable from the host.
   Note that there is no method to properly test link failure events using software utilities. Tools that deactivate connections, such as nmcli, show only the bonding driver's ability to handle port configuration changes and not actual link failure events.

2. Display the status of the bond:

   ```
   # cat /proc/net/bonding/bond0
   ```

17.6.2. Configuring a network bridge for network bonds by using nmcli

A network bridge for network bonds involves configuring a bond interface that combines multiple network interfaces for improved traffic handling. Therefore, VMs can access the network through the bonded network interfaces by using the network bridge. The **nmcli** utility creates and edits connection files from the command line required for the configuration.

Procedure

1. Create a bridge interface:

   ```
   # nmcli connection add type bridge con-name br0 ifname br0 ipv4.method disabled
   ipv6.method disabled
   ```

2. Add the **bond0** bond to the **br0** bridge:

   ```
   # nmcli connection modify bond0 master br0
   ```

3. Configure that Red Hat Enterprise Linux enables all ports automatically when the bridge is enabled:

   ```
   # nmcli connection modify br0 connection.autoconnect-ports 1
   ```

4. Reactivate the bridge:

```
# nmcli connection up br0
```

Verification

- Use the **ip** utility to display the link status of Ethernet devices that are ports of a specific bridge:

  ```
  # ip link show master br0
  6: bond0: <BROADCAST,MULTICAST,MASTER,UP,LOWER_UP> mtu 1500 qdisc noqueue
  master br0 state UP mode DEFAULT group default qlen 1000
      link/ether 52:54:00:38:a9:4d brd ff:ff:ff:ff:ff:ff
  ...
  ```

- Use the **bridge** utility to display the status of Ethernet devices that are ports of any bridge device:

  ```
  # bridge link show
  6: bond0: <BROADCAST,MULTICAST,MASTER,UP,LOWER_UP> mtu 1500 master br0
  state forwarding priority 32 cost 100
  ...
  ```

  To display the status for a specific Ethernet device, use the **bridge link show dev <ethernet_device_name>** command.

Additional resources

- **nm-settings(5)** man page

- **bridge(8)** man page

17.6.3. Creating a virtual network in libvirt with an existing bond interface

To enable virtual machines (VM) to use the **br0** bridge with the bond, first add a virtual network to the **libvirtd** service that uses this bridge.

Prerequisites

- You installed the **libvirt** package.

- You started and enabled the **libvirtd** service.

- You configured the **br0** device with the bond on Red Hat Enterprise Linux.

Procedure

1. Create the **~/bond0-bridge.xml** file with the following content:

   ```
   <network>
    <name>bond0-bridge</name>
    <forward mode="bridge" />
    <bridge name="br0" />
   </network>
   ```

2. Use the **~/bond0-bridge.xml** file to create a new virtual network in **libvirt**:

   ```
   # virsh net-define ~/bond0-bridge.xml
   ```

3. Remove the **~/bond0-bridge.xml** file:

   ```
   # rm ~/bond0-bridge.xml
   ```

4. Start the **bond0-bridge** virtual network:

   ```
   # virsh net-start bond0-bridge
   ```

5. Configure the **bond0-bridge** virtual network to start automatically when the **libvirtd** service starts:

   ```
   # virsh net-autostart bond0-bridge
   ```

Verification

- Display the list of virtual networks:

  ```
  # virsh net-list
  Name           State    Autostart   Persistent
  ----------------------------------------------------
  bond0-bridge     active     yes         yes
  ...
  ```

Additional resources

- **virsh(1)** man page

17.6.4. Configuring virtual machines to use a bond interface

To configure a VM to use a bridge device with a bond interface on the host, create a new VM that uses the **bond0-bridge** virtual network or update the settings of existing VMs to use this network.

Perform this procedure on the RHEL hosts.

Prerequisites

- You configured the **bond0-bridge** virtual network in **libvirtd**.

Procedure

1. To create a new VM and configure it to use the **bond0-bridge** network, pass the **--network network:bond0-bridge** option to the **virt-install** utility when you create the VM:

   ```
   # virt-install ... --network network:bond0-bridge
   ```

2. To change the network settings of an existing VM:

   a. Connect the VM’s network interface to the **bond0-bridge** virtual network:

```
# virt-xml <example_vm> --edit --network network=bond0-bridge
```

3. Shut down the VM, and start it again:

   ```
   # virsh shutdown <example_vm>
   # virsh start <example_vm>
   ```

Verification

- Display the virtual network interfaces of the VM on the host:

  ```
  # virsh domiflist <example_vm>
  Interface   Type     Source          Model    MAC
  -------------------------------------------------------------------
  vnet1       bridge   bond0-bridge   virtio   52:54:00:c5:98:1c
  ```

- Display the interfaces attached to the **br0** bridge:

  ```
  # ip link show master br0
  18: bond0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue master
  br0 state UNKNOWN mode DEFAULT group default qlen 1000
  link/ether 2a:53:bd:d5:b3:0a brd ff:ff:ff:ff:ff:ff

  19: vnet1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue master
  br0 state UNKNOWN mode DEFAULT group default qlen 1000
  link/ether 52:54:00:c5:98:1c brd ff:ff:ff:ff:ff:ff
  ...
  ```

  Note that the **libvirtd** service dynamically updates the bridge's configuration. When you start a VM which uses the **bond0-bridge** network, the corresponding **vnet*** device on the host appears as a port of the bridge.

Additional resources

- **virt-install(1)** man page
- **virt-xml(1)** man page
- **virsh(1)** man page
- **arping(8)** man page

17.7. CONFIGURING THE PASST USER-SPACE CONNECTION

If you require non-privileged access to a virtual network, for example when using a **session** connection of **libvirt**, you can configure your virtual machine (VM) to use the **passt** networking back end.

Prerequisites

- The **passt** package has been installed on your system.

  ```
  # dnf install passt
  ```

Procedure

1. Open the XML configuration of the VM on which you want to use a **passt** connection. For example:

```
# virsh edit <testguest1>
```

2. In the **<devices>** section, add an **<interface type='user'>** element that uses **passt** as its backend type.
For example, the following configuration sets up a **passt** connection that uses addresses and routes copied from the host interface associated with the first default route:

```
<devices>
  [...]
  <interface type='user'>
    <backend type='passt'/>
  </interface>
</devices>
```

Optionally, when using **passt**, you can specify multiple **<portForward>** elements to forward incoming network traffic for the host to this VM interface. You can also customize interface IP addresses. For example:

```
<devices>
  [...]
  <interface type='user'>
    <backend type='passt'/>
    <mac address="52:54:00:98:d8:b7"/>
    <source dev='eth0'/>
    <ip family='ipv4' address='192.0.2.1' prefix='24'/>
    <ip family='ipv6' address='::ffff:c000:201'/>
    <portForward proto='tcp'>
      <range start='2022' to='22'/>
    </portForward>
    <portForward proto='udp' address='1.2.3.4'>
       <range start='5000' end='5020' to='6000'/>
       <range start='5010' end='5015' exclude='yes'/>
    </portForward>
    <portForward proto='tcp' address='2001:db8:ac10:fd01::1:10' dev='eth0'>
      <range start='8080'/>
      <range start='4433' to='3444'/>
    </portForward>
  </interface>
</devices>
```

This example configuration sets up a **passt** connection with the following parameters:

- The VM copies the network routes for forwarding traffic from the **eth0** host interface.
- The interface MAC is set to **52:54:00:98:d8:b7**. If unset, a random one will be generated.
- The IPv4 address is set to **192.0.2.1/24**, and the IPv6 address is set to **::ffff:c000:201**.
- The TCP port **2022** on the host forwards its network traffic to port **22** on the VM.

- The TCP address **2001:db8:ac10:fd01::1:10** on host interface **eth0** and port **8080** forwards its network traffic to port **8080** on the VM. Port **4433** forwards to port **3444** on the VM.
- The UDP address **1.2.3.4** and ports **5000 - 5009** and **5016 - 5020** on the host forward their network traffic to ports **6000 - 6009** and **6016 - 6020** on the VM.

3. Save the XML configuration.

Verification

- Start or restart the VM you configured with **passt**:

  ```
  # virsh reboot <vm-name>
  # virsh start <vm-name>
  ```

  If the VM boots successfully, it is now using the **passt** networking backend.

Additional resources

- System and session connections in **libvirt**

17.8. ADDITIONAL RESOURCES

- Configuring and managing networking
- Attach specific network interface cards as SR-IOV devices to increase VM performance.

CHAPTER 18. OPTIMIZING VIRTUAL MACHINE PERFORMANCE

Virtual machines (VMs) always experience some degree of performance deterioration in comparison to the host. The following sections explain the reasons for this deterioration and provide instructions on how to minimize the performance impact of virtualization in RHEL 9, so that your hardware infrastructure resources can be used as efficiently as possible.

18.1. WHAT INFLUENCES VIRTUAL MACHINE PERFORMANCE

VMs are run as user-space processes on the host. The hypervisor therefore needs to convert the host's system resources so that the VMs can use them. As a consequence, a portion of the resources is consumed by the conversion, and the VM therefore cannot achieve the same performance efficiency as the host.

The impact of virtualization on system performance

More specific reasons for VM performance loss include:

- Virtual CPUs (vCPUs) are implemented as threads on the host, handled by the Linux scheduler.
- VMs do not automatically inherit optimization features, such as NUMA or huge pages, from the host kernel.
- Disk and network I/O settings of the host might have a significant performance impact on the VM.
- Network traffic typically travels to a VM through a software-based bridge.
- Depending on the host devices and their models, there might be significant overhead due to emulation of particular hardware.

The severity of the virtualization impact on the VM performance is influenced by a variety factors, which include:

- The number of concurrently running VMs.
- The amount of virtual devices used by each VM.
- The device types used by the VMs.

Reducing VM performance loss

RHEL 9 provides a number of features you can use to reduce the negative performance effects of virtualization. Notably:

- The **TuneD** service can automatically optimize the resource distribution and performance of your VMs.
- Block I/O tuning can improve the performances of the VM's block devices, such as disks.
- NUMA tuning can increase vCPU performance.
- Virtual networking can be optimized in various ways.

IMPORTANT

Tuning VM performance can have negative effects on other virtualization functions. For example, it can make migrating the modified VM more difficult.

18.2. OPTIMIZING VIRTUAL MACHINE PERFORMANCE BY USING TUNED

The **TuneD** utility is a tuning profile delivery mechanism that adapts RHEL for certain workload characteristics, such as requirements for CPU-intensive tasks or storage-network throughput responsiveness. It provides a number of tuning profiles that are pre-configured to enhance performance and reduce power consumption in a number of specific use cases. You can edit these profiles or create new profiles to create performance solutions tailored to your environment, including virtualized environments.

To optimize RHEL 9 for virtualization, use the following profiles:

- For RHEL 9 virtual machines, use the **virtual-guest** profile. It is based on the generally applicable ***throughput-performance*** profile, but also decreases the swappiness of virtual memory.
- For RHEL 9 virtualization hosts, use the **virtual-host** profile. This enables more aggressive writeback of dirty memory pages, which benefits the host performance.

Prerequisites

- The **TuneD** service is installed and enabled.

Procedure

To enable a specific **TuneD** profile:

1. List the available **TuneD** profiles.

```
# tuned-adm list

Available profiles:
- balanced             - General non-specialized TuneD profile
- desktop              - Optimize for the desktop use-case
[...]
- virtual-guest        - Optimize for running inside a virtual guest
- virtual-host         - Optimize for running KVM guests
Current active profile: balanced
```

2. Optional: Create a new **TuneD** profile or edit an existing **TuneD** profile.
   For more information, see Customizing TuneD profiles.

3. Activate a **TuneD** profile.

```
# tuned-adm profile selected-profile
```

- To optimize a virtualization host, use the *virtual-host* profile.

```
# tuned-adm profile virtual-host
```

- On a RHEL guest operating system, use the *virtual-guest* profile.

  ```
  # tuned-adm profile virtual-guest
  ```

Verification

1. Display the active profile for **TuneD**.

   ```
   # tuned-adm active
   Current active profile: virtual-host
   ```

2. Ensure that the **TuneD** profile settings have been applied on your system.

   ```
   # tuned-adm verify
   Verification succeeded, current system settings match the preset profile. See tuned log file
   ('/var/log/tuned/tuned.log') for details.
   ```

Additional resources

- Monitoring and managing system status and performance

18.3. VIRTUAL MACHINE PERFORMANCE OPTIMIZATION FOR SPECIFIC WORKLOADS

Virtual machines (VMs) are frequently dedicated to perform a specific workload. You can improve the performance of your VMs by optimizing their configuration for the intended workload.

Table 18.1. Recommended VM configurations for specific use cases

Use case	IOThread	vCPU pinning	vNUMA pinning	huge pages	multi-queue
Database	For database disks	**Yes**[*]	**Yes**[*]	**Yes**[*]	**Yes, see:** **multi-queue virtio-blk, virtio-scsi**
Virtualized Network Function (VNF)	No	**Yes**	**Yes**	**Yes**	**Yes, see:** **multi-queue virtio-net**
High Performance Computing (HPC)	No	**Yes**	**Yes**	**Yes**	No
Backup Server	For backup disks	No	No	No	**Yes, see:** **multi-queue virtio-blk, virtio-scsi**

Use case	IOThread	vCPU pinning	vNUMA pinning	huge pages	multi-queue
VM with many CPUs (Usually more than 32)	No	Yes*	Yes*	No	No
VM with large RAM (Usually more than 128 GB)	No	No	Yes*	**Yes**	No

* If the VM has enough CPUs and RAM to use more than one NUMA node.

NOTE

A VM can fit in more than one category of use cases. In this situation, you should apply all of the recommended configurations.

18.4. OPTIMIZING LIBVIRT DAEMONS

The **libvirt** virtualization suite works as a management layer for the RHEL hypervisor, and your **libvirt** configuration significantly impacts your virtualization host. Notably, RHEL 9 contains two different types of **libvirt** daemons, monolithic or modular, and which type of daemons you use affects how granularly you can configure individual virtualization drivers.

18.4.1. Types of libvirt daemons

RHEL 9 supports the following **libvirt** daemon types:

Monolithic libvirt

The traditional **libvirt** daemon, **libvirtd**, controls a wide variety of virtualization drivers, by using a single configuration file - **/etc/libvirt/libvirtd.conf**.
As such, **libvirtd** allows for centralized hypervisor configuration, but may use system resources inefficiently. Therefore, **libvirtd** will become unsupported in a future major release of RHEL.

However, if you updated to RHEL 9 from RHEL 8, your host still uses **libvirtd** by default.

Modular libvirt

Newly introduced in RHEL 9, modular **libvirt** provides a specific daemon for each virtualization driver. These include the following:

- **virtqemud** - A primary daemon for hypervisor management
- **virtinterfaced** - A secondary daemon for host NIC management
- **virtnetworkd** - A secondary daemon for virtual network management
- **virtnodedevd** - A secondary daemon for host physical device management
- **virtnwfilterd** - A secondary daemon for host firewall management

- **virtsecretd** - A secondary daemon for host secret management
- **virtstoraged** - A secondary daemon for storage management

Each of the daemons has a separate configuration file - for example **/etc/libvirt/virtqemud.conf**. As such, modular **libvirt** daemons provide better options for fine-tuning **libvirt** resource management.

If you performed a fresh install of RHEL 9, modular **libvirt** is configured by default.

Next steps

- If your RHEL 9 uses **libvirtd**, Red Hat recommends switching to modular daemons. For instructions, see Enabling modular libvirt daemons.

18.4.2. Enabling modular libvirt daemons

In RHEL 9, the **libvirt** library uses modular daemons that handle individual virtualization driver sets on your host. For example, the **virtqemud** daemon handles QEMU drivers.

If you performed a fresh install of a RHEL 9 host, your hypervisor uses modular **libvirt** daemons by default. However, if you upgraded your host from RHEL 8 to RHEL 9, your hypervisor uses the monolithic **libvirtd** daemon, which is the default in RHEL 8.

If that is the case, Red Hat recommends enabling the modular **libvirt** daemons instead, because they provide better options for fine-tuning **libvirt** resource management. In addition, **libvirtd** will become unsupported in a future major release of RHEL.

Prerequisites

- Your hypervisor is using the monolithic **libvirtd** service.

  ```
  # systemctl is-active libvirtd.service
  active
  ```

  If this command displays **active**, you are using **libvirtd**.

- Your virtual machines are shut down.

Procedure

1. Stop **libvirtd** and its sockets.

   ```
   $ systemctl stop libvirtd.service
   $ systemctl stop libvirtd{,-ro,-admin,-tcp,-tls}.socket
   ```

2. Disable **libvirtd** to prevent it from starting on boot.

   ```
   $ systemctl disable libvirtd.service
   $ systemctl disable libvirtd{,-ro,-admin,-tcp,-tls}.socket
   ```

3. Enable the modular **libvirt** daemons.

```
# for drv in qemu interface network nodedev nwfilter secret storage; do systemctl unmask
virt${drv}d.service; systemctl unmask virt${drv}d{,-ro,-admin}.socket; systemctl enable
virt${drv}d.service; systemctl enable virt${drv}d{,-ro,-admin}.socket; done
```

4. Start the sockets for the modular daemons.

   ```
   # for drv in qemu interface network nodedev nwfilter secret storage; do systemctl start
   virt${drv}d{,-ro,-admin}.socket; done
   ```

5. Optional: If you require connecting to your host from remote hosts, enable and start the virtualization proxy daemon.

   a. Check whether the **libvirtd-tls.socket** service is enabled on your system.

      ```
      # grep listen_tls /etc/libvirt/libvirtd.conf

      listen_tls = 0
      ```

   b. If **libvirtd-tls.socket** is not enabled (**listen_tls = 0**), activate **virtproxyd** as follows:

      ```
      # systemctl unmask virtproxyd.service
      # systemctl unmask virtproxyd{,-ro,-admin}.socket
      # systemctl enable virtproxyd.service
      # systemctl enable virtproxyd{,-ro,-admin}.socket
      # systemctl start virtproxyd{,-ro,-admin}.socket
      ```

   c. If **libvirtd-tls.socket** is enabled (**listen_tls = 1**), activate **virtproxyd** as follows:

      ```
      # systemctl unmask virtproxyd.service
      # systemctl unmask virtproxyd{,-ro,-admin,-tls}.socket
      # systemctl enable virtproxyd.service
      # systemctl enable virtproxyd{,-ro,-admin,-tls}.socket
      # systemctl start virtproxyd{,-ro,-admin,-tls}.socket
      ```

      To enable the TLS socket of **virtproxyd**, your host must have TLS certificates configured to work with **libvirt**. For more information, see the Upstream libvirt documentation.

Verification

1. Activate the enabled virtualization daemons.

   ```
   # virsh uri
   qemu:///system
   ```

2. Verify that your host is using the **virtqemud** modular daemon.

   ```
   # systemctl is-active virtqemud.service
   active
   ```

   If the status is **active**, you have successfully enabled modular **libvirt** daemons.

18.5. CONFIGURING VIRTUAL MACHINE MEMORY

To improve the performance of a virtual machine (VM), you can assign additional host RAM to the VM. Similarly, you can decrease the amount of memory allocated to a VM so the host memory can be allocated to other VMs or tasks.

18.5.1. Memory overcommitment

Virtual machines (VMs) running on a KVM hypervisor do not have dedicated blocks of physical RAM assigned to them. Instead, each VM functions as a Linux process where the host's Linux kernel allocates memory only when requested. In addition, the host's memory manager can move the VM's memory between its own physical memory and swap space. If memory overcommitment is enabled, the kernel can decide to allocate less physical memory than is requested by a VM, because often the requested amount of memory is not fully used by the VM's process.

By default, memory overcommitment is enabled in the Linux kernel and the kernel estimates the safe amount of memory overcommitment for VM's requests. However, the system can still become unstable with frequent overcommitment for memory-intensive workloads.

Memory overcommitment requires you to allocate sufficient swap space on the host physical machine to accommodate all VMs as well as enough memory for the host physical machine's processes. For instructions on the basic recommended swap space size, see What is the recommended swap size for Red Hat platforms? (Red Hat Knowledgebase).

Recommended methods to deal with memory shortages on the host:

- Allocate less memory per VM.
- Add more physical memory to the host.
- Use larger swap space.

IMPORTANT

A VM will run slower if it is swapped frequently. In addition, overcommitting can cause the system to run out of memory (OOM), which may lead to the Linux kernel shutting down important system processes.

Memory overcommit is not supported with device assignment. This is because when device assignment is in use, all virtual machine memory must be statically pre-allocated to enable direct memory access (DMA) with the assigned device.

Additional resources

- Virtual memory parameters
- What is the recommended swap size for Red Hat platforms? (Red Hat Knowledgebase)

18.5.2. Configuring virtual machines to use huge pages

In certain use cases, you can improve memory allocation for your virtual machines (VMs) by using huge pages instead of the default 4 KiB memory pages. For example, huge pages can improve performance for VMs with high memory utilization, such as database servers.

Prerequisites

- The host is configured to use huge pages in memory allocation. For instructions, see: Configuring HugeTLB at boot time

Procedure

1. Shut down the selected VM if it is running.

2. To configure a VM to use 1 GiB huge pages, open the XML definition of a VM for editing. For example, to edit a **testguest** VM, run the following command:

   ```
   # virsh edit testguest
   ```

3. Add the following lines to the **<memoryBacking>** section in the XML definition:

   ```
   <memoryBacking>
     <hugepages>
       <page size='1' unit='GiB'/>
     </hugepages>
   </memoryBacking>
   ```

Verification

1. Start the VM.

2. Confirm that the host has successfully allocated huge pages for the running VM. On the host, run the following command:

   ```
   # cat /proc/meminfo | grep Huge

   HugePages_Total:    4
   HugePages_Free:     2
   HugePages_Rsvd:     1
   Hugepagesize:       1024000 kB
   ```

   When you add together the number of free and reserved huge pages (**HugePages_Free** + **HugePages_Rsvd**), the result should be less than the total number of huge pages (**HugePages_Total**). The difference is the number of huge pages that is used by the running VM.

Additional resources

- Configuring huge pages

18.5.3. Adding and removing virtual machine memory by using virtio-mem

RHEL 9 provides the **virtio-mem** paravirtualized memory device. This device makes it possible to dynamically add or remove host memory in virtual machines (VMs). For example, you can use **virtio-mem** to move memory resources between running VMs or to resize VM memory in cloud setups based on your current requirements.

18.5.3.1. Overview of virtio-mem

virtio-mem is a paravirtualized memory device that can be used to dynamically add or remove host memory in virtual machines (VMs). For example, you can use this device to move memory resources between running VMs or to resize VM memory in cloud setups based on your current requirements.

By using **virtio-mem**, you can increase the memory of a VM beyond its initial size, and shrink it back to its original size, in units that can have the size of 4 to several hundred mebibytes (MiBs). Note, however, that **virtio-mem** also relies on a specific guest operating system configuration, especially to reliably unplug memory.

virtio-mem feature limitations

virtio-mem is currently not compatible with the following features:

- Using memory locking for real-time applications on the host
- Using encrypted virtualization on the host
- Combining **virtio-mem** with **memballoon** inflation and deflation on the host
- Unloading or reloading the **virtio_mem** driver in a VM
- Using vhost-user devices, with the exception of **virtiofs**

Additional resources

- Configuring memory onlining in virtual machines
- Attaching a virtio-mem device to virtual machines

18.5.3.2. Configuring memory onlining in virtual machines

Before using **virtio-mem** to attach memory to a running virtual machine (also known as memory hot-plugging), you must configure the virtual machine (VM) operating system to automatically set the hot-plugged memory to an online state. Otherwise, the guest operating system is not able to use the additional memory. You can choose from one of the following configurations for memory onlining:

- **online_movable**
- **online_kernel**
- **auto-movable**

To learn about differences between these configurations, see: Comparison of memory onlining configurations

Memory onlining is configured with udev rules by default in RHEL. However, when using **virtio-mem**, it is recommended to configure memory onlining directly in the kernel.

Prerequisites

- The host uses the Intel 64, AMD64, ARM 64, or IBM Z CPU architecture.
- The host uses one of the following operating system versions:
  - On Intel 64 and AMD64 hosts: RHEL 9.4 or later
  - On ARM 64 hosts: RHEL 9.6 or later

   - On IBM Z hosts: RHEL 9.7 or later

- VMs running on the host use one of the following operating system versions:
   - On Intel 64 and AMD64 hosts: RHEL 8.10, RHEL 9.4 or later, or RHEL 10.0 or later

     > **IMPORTANT**
     >
     > Unplugging memory from a running VM is disabled by default in RHEL 8.10 VMs.

   - On ARM 64 hosts: RHEL 9.6 or later or RHEL 10.0 or later
   - On IBM Z hosts: RHEL 9.7 or later or RHEL 10.1 or later

Procedure

- To set memory onlining to use the **online_movable** configuration in the VM:
   1. Set the **memhp_default_state** kernel command line parameter to **online_movable**:

      ```
      # grubby --update-kernel=ALL --remove-args=memhp_default_state --
      args=memhp_default_state=online_movable
      ```

   2. Reboot the VM.

- To set memory onlining to use the **online_kernel** configuration in the VM:
   1. Set the **memhp_default_state** kernel command line parameter to **online_kernel**:

      ```
      # grubby --update-kernel=ALL --remove-args=memhp_default_state --
      args=memhp_default_state=online_kernel
      ```

   2. Reboot the VM.

- To use the **auto-movable** memory onlining policy in the VM:
   1. Set the **memhp_default_state** kernel command line parameter to **online**:

      ```
      # grubby --update-kernel=ALL --remove-args=memhp_default_state --
      args=memhp_default_state=online
      ```

   2. Set the **memory_hotplug.online_policy** kernel command line parameter to **auto-movable**:

      ```
      # grubby --update-kernel=ALL --remove-args="memory_hotplug.online_policy" --
      args=memory_hotplug.online_policy=auto-movable
      ```

   3. Optional: To further tune the **auto-movable** onlining policy, change the **memory_hotplug.auto_movable_ratio** and **memory_hotplug.auto_movable_numa_aware** parameters:

      ```
      # grubby --update-kernel=ALL --remove-args="memory_hotplug.auto_movable_ratio" --
      args=memory_hotplug.auto_movable_ratio=<percentage>
      ```

```
# grubby --update-kernel=ALL --remove-
args="memory_hotplug.memory_auto_movable_numa_aware" --
args=memory_hotplug.auto_movable_numa_aware=<y/n>
```

- The **memory_hotplug.auto_movable_ratio parameter** sets the maximum ratio of memory only available for movable allocations compared to memory available for any allocations. The ratio is expressed in percents and the default value is: *301* (%), which is a 3:1 ratio.

- The **memory_hotplug.auto_movable_numa_aware** parameter controls whether the **memory_hotplug.auto_movable_ratio** parameter applies to memory across all available NUMA nodes or only for memory within a single NUMA node. The default value is: *y* (yes)
  For example, if the maximum ratio is set to 301% and the **memory_hotplug.auto_movable_numa_aware** is set to *y* (yes), than the 3:1 ratio is applied even within the NUMA node with the attached **virtio-mem** device. If the parameter is set to *n* (no), the maximum 3:1 ratio is applied only for all the NUMA nodes as a whole.

  Additionally, if the ratio is not exceeded, the newly hot-plugged memory will be available only for movable allocations. Otherwise, the newly hot-plugged memory will be available for both movable and unmovable allocations.

4. Reboot the VM.

Verification

- To see if the **online_movable** configuration has been set correctly, check the current value of the **memhp_default_state** kernel parameter:

  ```
  # cat /sys/devices/system/memory/auto_online_blocks

  online_movable
  ```

- To see if the **online_kernel** configuration has been set correctly, check the current value of the **memhp_default_state** kernel parameter:

  ```
  # cat /sys/devices/system/memory/auto_online_blocks

  online_kernel
  ```

- To see if the **auto-movable** configuration has been set correctly, check the following kernel parameters:

  - **memhp_default_state**:

    ```
    # cat /sys/devices/system/memory/auto_online_blocks

    online
    ```

  - **memory_hotplug.online_policy**:

```
# cat /sys/module/memory_hotplug/parameters/online_policy

auto-movable
```

- **memory_hotplug.auto_movable_ratio**:

```
# cat /sys/module/memory_hotplug/parameters/auto_movable_ratio

301
```

- **memory_hotplug.auto_movable_numa_aware**:

```
# cat /sys/module/memory_hotplug/parameters/auto_movable_numa_aware

y
```

Additional resources

- Overview of virtio-mem
- Attaching a virtio-mem device to virtual machines
- Configuring Memory Hot(Un)Plug

18.5.3.3. Attaching a virtio-mem device to virtual machines

To attach additional memory to a running virtual machine (also known as memory hot-plugging) and afterwards be able to resize the hot-plugged memory, you can use a **virtio-mem** device. Specifically, you can use libvirt XML configuration files and **virsh** commands to define and attach **virtio-mem** devices to virtual machines (VMs).

Prerequisites

- The host uses the Intel 64, AMD64, ARM 64, or IBM Z CPU architecture.
- The host uses one of the following operating system versions:
  - On Intel 64 and AMD64 hosts: RHEL 9.4 or later
  - On ARM 64 hosts: RHEL 9.6 or later
  - On IBM Z hosts: RHEL 9.7 or later
- VMs running on the host use one of the following operating system versions:
  - On Intel 64 and AMD64 hosts: RHEL 8.10, RHEL 9.4 or later, or RHEL 10.0 or later

    IMPORTANT

    Unplugging memory from a running VM is disabled by default in RHEL 8.10 VMs.

  - On ARM 64 hosts: RHEL 9.6 or later or RHEL 10.0 or later

   - On IBM Z hosts: RHEL 9.7 or later or RHEL 10.1 or later

- The VM has memory onlining configured. For instructions, see: Configuring memory onlining in virtual machines

Procedure

1. Ensure the XML configuration of the target VM includes the **maxMemory** parameter:

```
# virsh edit testguest1

<domain type='kvm'>
  <name>testguest1</name>
  ...
  <maxMemory unit='GiB'>128</maxMemory>
  ...
</domain>
```

   In this example, the XML configuration of the **testguest1** VM defines a **maxMemory** parameter with a 128 gibibyte (GiB) size. The **maxMemory** size specifies the maximum memory the VM can use, which includes both initial and hot-plugged memory.

2. Create and open an XML file to define **virtio-mem** devices on the host, for example:

```
# vim virtio-mem-device.xml
```

3. Add XML definitions of **virtio-mem** devices to the file and save it:

```
<memory model='virtio-mem'>
        <target>
                <size unit='GiB'>48</size>
                <node>0</node>
                <block unit='MiB'>2</block>
                <requested unit='GiB'>16</requested>
                <current unit='GiB'>16</current>
        </target>
        <alias name='ua-virtiomem0'/>
        <address type='pci' domain='0x0000' bus='0x00' slot='0x02' function='0x0'/>
</memory>
<memory model='virtio-mem'>
        <target>
                <size unit='GiB'>48</size>
                <node>1</node>
                <block unit='MiB'>2</block>
                <requested unit='GiB'>0</requested>
                <current unit='GiB'>0</current>
        </target>
        <alias name='ua-virtiomem1'/>
        <address type='pci' domain='0x0000' bus='0x00' slot='0x04' function='0x0'/>
</memory>
```

   In this example, two **virtio-mem** devices are defined with the following parameters:

   - **size**: This is the maximum size of the device. In the example, it is 48 GiB. The **size** must be a multiple of the **block** size.

- **node**: This is the assigned vNUMA node for the **virtio-mem** device.

- **block**: This is the block size of the device. It must be at least the size of the Transparent Huge Page (THP), which is 2 MiB on Intel 64 and AMD64 CPU architecture. On ARM64 architecture, the size of THP can be 2 MiB or 512 MiB depending on the base page size. The 2 MiB block size on Intel 64 or AMD64 architecture is usually a good default choice. When using **virtio-mem** with *Virtual Function I/O (VFIO)* or *mediated devices (mdev)*, the total number of blocks across all **virtio-mem** devices must not be larger than 32768, otherwise the plugging of RAM might fail.

- **requested**: This is the amount of memory you attach to the VM with the **virtio-mem** device. However, it is just a request towards the VM and it might not be resolved successfully, for example if the VM is not properly configured. The **requested** size must be a multiple of the **block** size and cannot exceed the maximum defined **size**.

- **current**: This represents the current size the **virtio-mem** device provides to the VM. The **current** size can differ from the **requested** size, for example when requests cannot be completed or when rebooting the VM.

- **alias**: This is an optional user-defined alias that you can use to specify the intended **virtio-mem** device, for example when editing the device with libvirt commands. All user-defined aliases in libvirt must start with the *"ua-"* prefix.
  Apart from these specific parameters, **libvirt** handles the **virtio-mem** device like any other PCI device. For more information on managing PCI devices attached to VMs, see: Managing virtual devices

4. Use the XML file to attach the defined **virtio-mem** devices to a VM. For example, to permanently attach the two devices defined in the **virtio-mem-device.xml** to the running **testguest1** VM:

   ```
   # virsh attach-device testguest1 virtio-mem-device.xml --live --config
   ```

   The **--live** option attaches the device to a running VM only, without persistence between boots. The **--config** option makes the configuration changes persistent. You can also attach the device to a shutdown VM without the **--live** option.

5. Optional: To dynamically change the **requested** size of a **virtio-mem** device attached to a running VM, use the **virsh update-memory-device** command:

   ```
   # virsh update-memory-device testguest1 --alias ua-virtiomem0 --requested-size 4GiB
   ```

   In this example:

   - **testguest1** is the VM you want to update.

   - **--alias ua-virtiomem0** is the **virtio-mem** device specified by a previously defined alias.

   - **--requested-size 4GiB** changes the **requested** size of the **virtio-mem** device to 4 GiB.

WARNING

Unplugging memory from a running VM by reducing the **requested** size might be unreliable. Whether this process succeeds depends on various factors, such as the memory onlining policy that is used.

In some cases, the guest operating system cannot complete the request successfully, because changing the amount of hot-plugged memory is not possible at that time.

Additionally, unplugging memory from a running VM is disabled by default in RHEL 8.10 VMs.

6. Optional: To unplug a **virtio-mem** device from a shut-down VM, use the **virsh detach-device** command:

```
# virsh detach-device testguest1 virtio-mem-device.xml
```

7. Optional: To unplug a **virtio-mem** device from a running VM:

   a. Change the **requested** size of the **virtio-mem** device to 0, otherwise the attempt to unplug a **virtio-mem** device from a running VM will fail.

   ```
   # virsh update-memory-device testguest1 --alias ua-virtiomem0 --requested-size 0
   ```

   b. Unplug a **virtio-mem** device from the running VM:

   ```
   # virsh detach-device testguest1 virtio-mem-device.xml --config
   ```

Verification

- In the VM, check the available RAM and see if the total amount now includes the hot-plugged memory:

```
# free -h

        total    used    free   shared  buff/cache   available
Mem:     31Gi    5.5Gi   14Gi   1.3Gi   11Gi         23Gi
Swap:    8.0Gi   0B      8.0Gi
```

```
# numactl -H

available: 1 nodes (0)
node 0 cpus: 0 1 2 3 4 5 6 7
node 0 size: 29564 MB
node 0 free: 13351 MB
node distances:
node   0
  0:  10
```

- The current amount of plugged-in RAM can be also viewed on the host by displaying the XML configuration of the running VM:

  ```
  # virsh dumpxml testguest1

  <domain type='kvm'>
   <name>testguest1</name>
   ...
   <currentMemory unit='GiB'>31</currentMemory>
   ...
   <memory model='virtio-mem'>
       <target>
         <size unit='GiB'>48</size>
         <node>0</node>
         <block unit='MiB'>2</block>
         <requested unit='GiB'>16</requested>
         <current unit='GiB'>16</current>
       </target>
       <alias name='ua-virtiomem0'/>
       <address type='pci' domain='0x0000' bus='0x08' slot='0x00' function='0x0'/>
   ...
  </domain>
  ```

  In this example:

  - **<currentMemory unit='GiB'>31</currentMemory>** represents the total RAM available in the VM from all sources.
  - **<current unit='GiB'>16</current>** represents the current size of the plugged-in RAM provided by the **virtio-mem** device.

Additional resources

- Overview of virtio-mem
- Configuring memory onlining in virtual machines

18.5.3.4. Comparison of memory onlining configurations

When attaching memory to a running RHEL virtual machine (also known as memory hot-plugging), you must set the hot-plugged memory to an online state in the virtual machine (VM) operating system. Otherwise, the system will not be able to use the memory.

The following table summarizes the main considerations when choosing between the available memory onlining configurations.

Table 18.2. Comparison of memory onlining configurations

Configuration name	Unplugging memory from a VM	A risk of creating a memory zone imbalance	A potential use case	Memory requirements of the intended workload

Configuration name	Unplugging memory from a VM	A risk of creating a memory zone imbalance	A potential use case	Memory requirements of the intended workload
online_movable	Hot-plugged memory can be reliably unplugged.	Yes	Hot-plugging a comparatively small amount of memory	Mostly user-space memory
auto-movable	Movable portions of hot-plugged memory can be reliably unplugged.	Minimal	Hot-plugging a large amount of memory	Mostly user-space memory
online_kernel	Hot-plugged memory cannot be reliably unplugged.	No	Unreliable memory unplugging is acceptable.	User-space or kernel-space memory

A *zone imbalance* is a lack of available memory pages in one of the Linux memory zones. A *zone imbalance* can negatively impact the system performance. For example, the kernel might crash if it runs out of free memory for unmovable allocations. Usually, movable allocations contain mostly user-space memory pages and unmovable allocations contain mostly kernel-space memory pages.

Additional resources

- Onlining and Offlining Memory Blocks
- Zone Imbalances
- Configuring memory onlining in virtual machines

18.5.4. Additional resources

- Attaching devices to virtual machines .

18.6. OPTIMIZING VIRTUAL MACHINE I/O PERFORMANCE

The input and output (I/O) capabilities of a virtual machine (VM) can significantly limit the VM's overall efficiency. To address this, you can optimize a VM's I/O by configuring block I/O parameters.

18.6.1. Tuning block I/O in virtual machines

When multiple block devices are being used by one or more VMs, it might be important to adjust the I/O priority of specific virtual devices by modifying their *I/O weights*.

Increasing the I/O weight of a device increases its priority for I/O bandwidth, and therefore provides it with more host resources. Similarly, reducing a device's weight makes it consume less host resources.

NOTE

Each device's **weight** value must be within the **100** to **1000** range. Alternatively, the value can be **0**, which removes that device from per-device listings.

Procedure

To display and set a VM's block I/O parameters:

1. Display the current **<blkio>** parameters for a VM:
   # virsh dumpxml *VM-name*

   ```
   <domain>
     [...]
     <blkiotune>
       <weight>800</weight>
       <device>
         <path>/dev/sda</path>
         <weight>1000</weight>
       </device>
       <device>
         <path>/dev/sdb</path>
         <weight>500</weight>
       </device>
     </blkiotune>
     [...]
   </domain>
   ```

2. Edit the I/O weight of a specified device:

   ```
   # virsh blkiotune VM-name --device-weights device, I/O-weight
   ```

   For example, the following changes the weight of the */dev/sda* device in the *testguest1* VM to 500.

   ```
   # virsh blkiotune testguest1 --device-weights /dev/sda, 500
   ```

Verification

- Check that the VM's block I/O parameters have been configured correctly.

  ```
  # virsh blkiotune testguest1

  Block I/O tuning parameters for domain testguest1:

    weight                  : 800
    device_weight               : [
                           {"sda": 500},
                          ]
  ...
  ```

IMPORTANT

Certain kernels do not support setting I/O weights for specific devices. If the previous step does not display the weights as expected, it is likely that this feature is not compatible with your host kernel.

18.6.2. Disk I/O throttling in virtual machines

When several VMs are running simultaneously, they can interfere with system performance by using excessive disk I/O. Disk I/O throttling in KVM virtualization provides the ability to set a limit on disk I/O requests sent from the VMs to the host machine. This can prevent a VM from over-utilizing shared resources and impacting the performance of other VMs.

To enable disk I/O throttling, set a limit on disk I/O requests sent from each block device attached to VMs to the host machine.

Procedure

1. Use the **virsh domblklist** command to list the names of all the disk devices on a specified VM.

```
# virsh domblklist rollin-coal
Target     Source
------------------------------------------------
vda        /var/lib/libvirt/images/rollin-coal.qcow2
sda        -
sdb        /home/horridly-demanding-processes.iso
```

2. Find the host block device where the virtual disk that you want to throttle is mounted.
   For example, if you want to throttle the **sdb** virtual disk from the previous step, the following output shows that the disk is mounted on the **/dev/nvme0n1p3** partition.

```
$ lsblk
NAME                                          MAJ:MIN RM   SIZE RO TYPE  MOUNTPOINT
zram0                                         252:0    0     4G  0 disk  [SWAP]
nvme0n1                                       259:0    0 238.5G  0 disk
 ├─nvme0n1p1                                  259:1    0   600M  0 part  /boot/efi
 ├─nvme0n1p2                                  259:2    0     1G  0 part  /boot
 └─nvme0n1p3                                  259:3    0 236.9G  0 part
   └─luks-a1123911-6f37-463c-b4eb-fxzy1ac12fea 253:0    0 236.9G  0 crypt /home
```

3. Set I/O limits for the block device by using the **virsh blkiotune** command.

```
# virsh blkiotune VM-name --parameter device,limit
```

The following example throttles the **sdb** disk on the **rollin-coal** VM to 1000 read and write I/O operations per second and to 50 MB per second read and write throughput.

```
# virsh blkiotune rollin-coal --device-read-iops-sec /dev/nvme0n1p3,1000 --device-write-iops-sec /dev/nvme0n1p3,1000 --device-write-bytes-sec /dev/nvme0n1p3,52428800 --device-read-bytes-sec /dev/nvme0n1p3,52428800
```

Additional resources

- Disk I/O throttling can be useful in various situations, for example when VMs belonging to different customers are running on the same host, or when quality of service guarantees are given for different VMs. Disk I/O throttling can also be used to simulate slower disks.
- I/O throttling can be applied independently to each block device attached to a VM and supports limits on throughput and I/O operations.
- Red Hat does not support using the **virsh blkdeviotune** command to configure I/O throttling in VMs. For more information about unsupported features when using RHEL 9 as a VM host, see Unsupported features in RHEL 9 virtualization .

18.6.3. Enabling multi-queue on storage devices

When using **virtio-blk** or **virtio-scsi** storage devices in your virtual machines (VMs), the *multi-queue* feature provides improved storage performance and scalability. It enables each virtual CPU (vCPU) to have a separate queue and interrupt to use without affecting other vCPUs.

The *multi-queue* feature is enabled by default for the **Q35** machine type, however you must enable it manually on the **i440FX** machine type. You can tune the number of queues to be optimal for your workload, however the optimal number differs for each type of workload and you must test which number of queues works best in your case.

Procedure

1. To enable **multi-queue** on a storage device, edit the XML configuration of the VM.

```
# virsh edit <example_vm>
```

2. In the XML configuration, find the intended storage device and change the **queues** parameter to use multiple I/O queues. Replace *N* with the number of vCPUs in the VM, up to 16.

   - A **virtio-blk** example:

```
<disk type='block' device='disk'>
  <driver name='qemu' type='raw' queues='N'/>
  <source dev='/dev/sda'/>
  <target dev='vda' bus='virtio'/>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x04' function='0x0'/>
</disk>
```

   - A **virtio-scsi** example:

```
<controller type='scsi' index='0' model='virtio-scsi'>
   <driver queues='N' />
</controller>
```

3. Restart the VM for the changes to take effect.

18.6.4. Configuring dedicated IOThreads

To improve the Input/Output (IO) performance of a disk on your virtual machine (VM), you can configure a dedicated **IOThread** that is used to manage the IO operations of the VM's disk.

Normally, the IO operations of a disk are a part of the main QEMU thread, which can decrease the responsiveness of the VM as a whole during intensive IO workloads. By separating the IO operations to a dedicated **IOThread**, you can significantly increase the responsiveness and performance of your VM.

Procedure

1. Shut down the selected VM if it is running.

2. On the host, add or edit the **<iothreads>** tag in the XML configuration of the VM. For example, to create a single **IOThread** for a **testguest1** VM:

```
# virsh edit <testguest1>

<domain type='kvm'>
  <name>testguest1</name>
  ...
  <vcpu placement='static'>8</vcpu>
  <iothreads>1</iothreads>
  ...
</domain>
```

NOTE

For optimal results, use only 1-2 **IOThreads** per CPU on the host.

3. Assign a dedicated **IOThread**` to a VM disk. For example, to assign an **IOThread** with ID of **1** to a disk on the **testguest1** VM:

```
# virsh edit <testguest1>

<domain type='kvm'>
  <name>testguest1</name>
  ...
  <devices>
    <disk type='file' device='disk'>
      <driver name='qemu' type='raw' cache='none' io='native' iothread='1'/>
      <source file='/var/lib/libvirt/images/test-disk.raw'/>
      <target dev='vda' bus='virtio'/>
      <address type='pci' domain='0x0000' bus='0x04' slot='0x00' function='0x0'/>
    </disk>
    ...
  </devices>
  ...
</domain>
```

NOTE

IOThread IDs start from 1 and you must dedicate only a single **IOThread** to a disk.

Usually, a one dedicated **IOThread** per VM is sufficient for optimal performance.

4. [illegible]

4. When using **virtio-scsi** storage devices, assign a dedicated **IOThread** to the **virtio-scsi** controller. For example, to assign an **IOThread** with ID of **1** to a controller on the **testguest1** VM:

```
# virsh edit <testguest1>

<domain type='kvm'>
  <name>testguest1</name>
  ...
  <devices>
    <controller type='scsi' index='0' model='virtio-scsi'>
      <driver iothread='1'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x0b' function='0x0'/>
    </controller>
    ...
  </devices>
  ...
</domain>
```

Verification

- Evaluate the impact of your changes on your VM performance. For details, see: Virtual machine performance monitoring tools

18.6.5. Configuring virtual disk caching

KVM provides several virtual disk caching modes. For intensive Input/Output (IO) workloads, selecting the optimal caching mode can significantly increase the virtual machine (VM) performance.

+

Virtual disk cache modes overview

writethrough

Host page cache is used for reading only. Writes are reported as completed only when the data has been committed to the storage device. The sustained IO performance is decreased but this mode has good write guarantees.

writeback

Host page cache is used for both reading and writing. Writes are reported as complete when data reaches the host’s memory cache, not physical storage. This mode has faster IO performance than **writethrough** but it is possible to lose data on host failure.

none

Host page cache is bypassed entirely. This mode relies directly on the write queue of the physical disk, so it has a predictable sustained IO performance and offers good write guarantees on a stable guest. It is also a safe cache mode for VM live migration.

Procedure

1. Shut down the selected VM if it is running.

2. Edit the XML configuration of the selected VM.

```
# virsh edit <vm_name>
```

–

3. Find the disk device and edit the **cache** option in the **driver** tag.

```
<domain type='kvm'>
  <name>testguest1</name>
  ...
  <devices>
    <disk type='file' device='disk'>
      <driver name='qemu' type='raw' cache='none' io='native' iothread='1'/>
      <source file='/var/lib/libvirt/images/test-disk.raw'/>
      <target dev='vda' bus='virtio'/>
      <address type='pci' domain='0x0000' bus='0x04' slot='0x00' function='0x0'/>
    </disk>
    ...
  </devices>
  ...
</domain>
```

18.7. OPTIMIZING VIRTUAL MACHINE CPU PERFORMANCE

Much like physical CPUs in host machines, vCPUs are critical to virtual machine (VM) performance. As a result, optimizing vCPUs can have a significant impact on the resource efficiency of your VMs. To optimize your vCPU:

1. Adjust how many host CPUs are assigned to the VM. You can do this using the CLI or the web console.

2. Ensure that the vCPU model is aligned with the CPU model of the host. For example, to set the *testguest1* VM to use the CPU model of the host:

   ```
   # virt-xml testguest1 --edit --cpu host-model
   ```

   On an ARM 64 system, use **--cpu host-passthrough**.

3. Manage kernel same-page merging (KSM) .

4. If your host machine uses Non-Uniform Memory Access (NUMA), you can also **configure NUMA** for its VMs. This maps the host’s CPU and memory processes onto the CPU and memory processes of the VM as closely as possible. In effect, NUMA tuning provides the vCPU with a more streamlined access to the system memory allocated to the VM, which can improve the vCPU processing effectiveness.
   For details, see Configuring NUMA in a virtual machine and Virtual machine performance optimization for specific workloads.

18.7.1. vCPU overcommitment

vCPU overcommitment allows you to have a setup where the sum of all vCPUs in virtual machines (VMs) running on a host exceeds the number of physical CPUs on the host. However, you might experience performance deterioration when simultaneously running more cores in your VMs than are physically available on the host.

For best performance, assign VMs with only as many vCPUs as are required to run the intended workloads in each VM.

vCPU overcommitment recommendations:

- Assign the minimum amount of vCPUs required by by the VM’s workloads for best performance.
- Avoid overcommitting vCPUs in production without extensive testing.
- If overcomitting vCPUs, the safe ratio is typically 5 vCPUs to 1 physical CPU for loads under 100%.
- It is not recommended to have more than 10 total allocated vCPUs per physical processor core.
- Monitor CPU usage to prevent performance degradation under heavy loads.

IMPORTANT

Applications that use 100% of memory or processing resources may become unstable in overcommitted environments. Do not overcommit memory or CPUs in a production environment without extensive testing, as the CPU overcommit ratio is workload-dependent.

18.7.2. Adding and removing virtual CPUs by using the command line

To increase or optimize the CPU performance of a virtual machine (VM), you can add or remove virtual CPUs (vCPUs) assigned to the VM.

When performed on a running VM, this is also referred to as vCPU hot plugging and hot unplugging. However, note that vCPU hot unplug is not supported in RHEL 9, and Red Hat highly discourages its use.

Prerequisites

- Optional: View the current state of the vCPUs in the targeted VM. For example, to display the number of vCPUs on the *testguest* VM:

  ```
  # virsh vcpucount testguest
  maximum      config         4
  maximum      live           2
  current      config         2
  current      live           1
  ```

  This output indicates that *testguest* is currently using 1 vCPU, and 1 more vCPu can be hot plugged to it to increase the VM’s performance. However, after reboot, the number of vCPUs *testguest* uses will change to 2, and it will be possible to hot plug 2 more vCPUs.

Procedure

1. Adjust the maximum number of vCPUs that can be attached to a VM, which takes effect on the VM’s next boot.
   For example, to increase the maximum vCPU count for the *testguest* VM to 8:

   ```
   # virsh setvcpus testguest 8 --maximum --config
   ```

   Note that the maximum may be limited by the CPU topology, host hardware, the hypervisor, and other factors.

2. Adjust the current number of vCPUs attached to a VM, up to the maximum configured in the previous step. For example:

   a. To increase the number of vCPUs attached to the running *testguest* VM to 4:

- To increase the number of vCPUs attached to the running *testguest* VM to 4:

  ```
  # virsh setvcpus testguest 4 --live
  ```

  This increases the VM's performance and host load footprint of *testguest* until the VM's next boot.

- To permanently decrease the number of vCPUs attached to the *testguest* VM to 1:

  ```
  # virsh setvcpus testguest 1 --config
  ```

  This decreases the VM's performance and host load footprint of *testguest* after the VM's next boot. However, if needed, additional vCPUs can be hot plugged to the VM to temporarily increase its performance.

Verification

- Confirm that the current state of vCPU for the VM reflects your changes.

  ```
  # virsh vcpucount testguest
  maximum      config         8
  maximum      live           4
  current      config         1
  current      live           4
  ```

Additional resources

- Managing virtual CPUs by using the web console

18.7.3. Managing virtual CPUs by using the web console

By using the RHEL 9 web console, you can review and configure virtual CPUs used by virtual machines (VMs) to which the web console is connected.

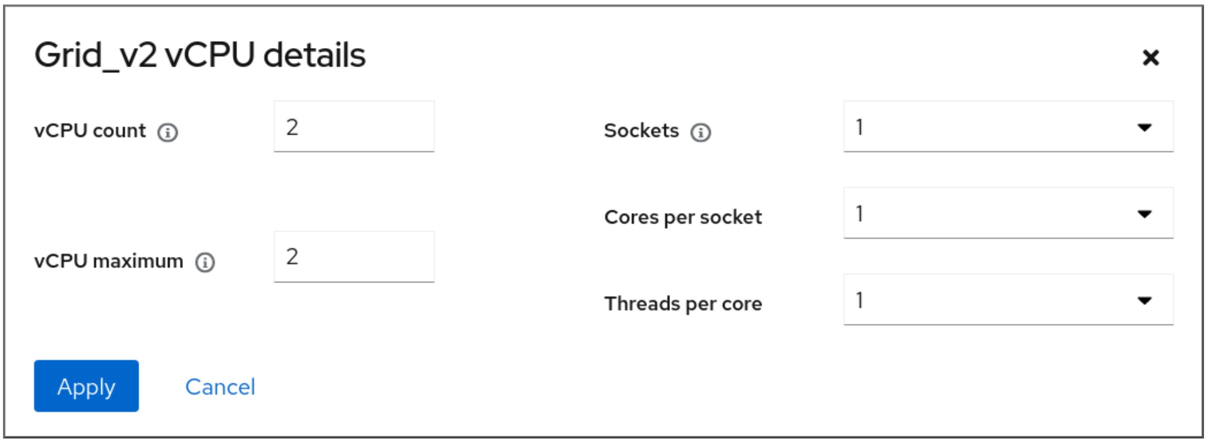
Prerequisites

- 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 web console VM plug-in 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 **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with an Overview section with basic information about the selected VM and a Console section to access the VM's graphical interface.

3. Click **edit** next to the number of vCPUs in the Overview pane.
The vCPU details dialog appears.



Grid_v2 vCPU details

vCPU count: 2

vCPU maximum: 2

Sockets: 1

Cores per socket: 1

Threads per core: 1

1. Configure the virtual CPUs for the selected VM.

    - **vCPU Count** - The number of vCPUs currently in use.

        NOTE

        The vCPU count cannot be greater than the vCPU Maximum.

    - **vCPU Maximum** - The maximum number of virtual CPUs that can be configured for the VM. If this value is higher than the **vCPU Count**, additional vCPUs can be attached to the VM.

    - **Sockets** - The number of sockets to expose to the VM.

    - **Cores per socket** - The number of cores for each socket to expose to the VM.

    - **Threads per core** - The number of threads for each core to expose to the VM.
    Note that the **Sockets**, **Cores per socket**, and **Threads per core** options adjust the CPU topology of the VM. This may be beneficial for vCPU performance and may impact the functionality of certain software in the guest OS. If a different setting is not required by your deployment, keep the default values.

2. Click **Apply**.
The virtual CPUs for the VM are configured.

    NOTE

    Changes to virtual CPU settings only take effect after the VM is restarted.

Additional resources

- Adding and removing virtual CPUs by using the command line

18.7.4. Configuring NUMA in a virtual machine

The following methods can be used to configure Non-Uniform Memory Access (NUMA) settings of a virtual machine (VM) on a RHEL 9 host.

For ease of use, you can set up a VM's NUMA configuration by using automated utilities and services. However, manual NUMA setup is more likely to yield a significant performance improvement.

Prerequisites

- The host is a NUMA-compatible machine. To detect whether this is the case, use the **virsh nodeinfo** command and see the **NUMA cell(s)** line:

  ```
  # virsh nodeinfo
  CPU model:           x86_64
  CPU(s):              48
  CPU frequency:       1200 MHz
  CPU socket(s):       1
  Core(s) per socket:  12
  Thread(s) per core:  2
  NUMA cell(s):        2
  Memory size:         67012964 KiB
  ```

  If the value of the line is 2 or greater, the host is NUMA-compatible.

- **Optional:** You have the **numactl** package installed on the host.

  ```
  # dnf install numactl
  ```

Procedure

Automatic methods

- Set the VM's NUMA policy to **Preferred**. For example, to configure the *testguest5* VM:

  ```
  # virt-xml testguest5 --edit --vcpus placement=auto
  # virt-xml testguest5 --edit --numatune mode=preferred
  ```

- Use the **numad** service to automatically align the VM CPU with memory resources.

  ```
  # echo 1 > /proc/sys/kernel/numa_balancing
  ```

- Start the **numad** service to automatically align the VM CPU with memory resources.

  ```
  # systemctl start numad
  ```

Manual methods

To manually tune NUMA settings, you can specify which host NUMA nodes will be assigned specifically to a certain VM. This can improve the host memory usage by the VM's vCPU.

1. **Optional:** Use the **numactl** command to view the NUMA topology on the host:

   ```
   # numactl --hardware

   available: 2 nodes (0-1)
   node 0 size: 18156 MB
   node 0 free: 9053 MB
   node 1 size: 18180 MB
   ```

```
node 1 free: 6853 MB
node distances:
node   0   1
  0:  10  20
  1:  20  10
```

2. Edit the XML configuration of a VM to assign CPU and memory resources to specific NUMA nodes. For example, the following configuration sets *testguest6* to use vCPUs 0-7 on NUMA node **0** and vCPUS 8-15 on NUMA node **1**. Both nodes are also assigned 16 GiB of VM's memory.

```
# virsh edit <testguest6>

<domain type='kvm'>
  <name>testguest6</name>
  ...
  <vcpu placement='static'>16</vcpu>
  ...
  <cpu ...>
    <numa>
      <cell id='0' cpus='0-7' memory='16' unit='GiB'/>
      <cell id='1' cpus='8-15' memory='16' unit='GiB'/>
    </numa>
  ...
</domain>
```

3. If the VM is running, restart it to apply the configuration.

NOTE

For best performance results, it is recommended to respect the maximum memory size for each NUMA node on the host.

Known issues

- NUMA tuning currently cannot be performed on IBM Z hosts .

Additional resources

- Virtual machine performance optimization for specific workloads
- Virtual machine performance optimization for specific workloads using the **numastat** utility

18.7.5. Configuring virtual CPU pinning

To improve the CPU performance of a virtual machine (VM), you can pin a virtual CPU (vCPU) to a specific physical CPU thread on the host. This ensures that the vCPU will have its own dedicated physical CPU thread, which can significantly improve the vCPU performance.

To further optimize the CPU performance, you can also pin QEMU process threads associated with a specified VM to a specific host CPU.

Procedure

1. Check the CPU topology on the host:

```
# lscpu -p=node,cpu

Node,CPU
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
1,0
1,1
1,2
1,3
1,4
1,5
1,6
1,7
```

   In this example, the output contains NUMA nodes and the available physical CPU threads on the host.

2. Check the number of vCPU threads inside the VM:

```
# lscpu -p=node,cpu

Node,CPU
0,0
0,1
0,2
0,3
```

   In this example, the output contains NUMA nodes and the available vCPU threads inside the VM.

3. Pin specific vCPU threads from a VM to a specific host CPU or range of CPUs. This is recommended as a safe method of vCPU performance improvement.
   For example, the following commands pin vCPU threads 0 to 3 of the *testguest6* VM to host CPUs 1, 3, 5, 7, respectively:

```
# virsh vcpupin testguest6 0 1
# virsh vcpupin testguest6 1 3
# virsh vcpupin testguest6 2 5
# virsh vcpupin testguest6 3 7
```

4. Optional: Verify whether the vCPU threads are successfully pinned to CPUs.

```
# virsh vcpupin testguest6
VCPU   CPU Affinity
----------------------
0      1
```

```
1    3
2    5
3    7
```

5. After pinning vCPU threads, you can also pin QEMU process threads associated with a specified VM to a specific host CPU or range of CPUs. This can further help the QEMU process to run more efficiently on the physical CPU.
   For example, the following commands pin the QEMU process thread of *testguest6* to CPUs 2 and 4, and verify this was successful:

```
# virsh emulatorpin testguest6 2,4
# virsh emulatorpin testguest6
emulator: CPU Affinity
----------------------------------
      *: 2,4
```

18.7.6. Configuring virtual CPU capping

You can use virtual CPU (vCPU) capping to limit the amount of CPU resources a virtual machine (VM) can use. vCPU capping can improve the overall performance by preventing excessive use of host's CPU resources by a single VM and by making it easier for the hypervisor to manage CPU scheduling.

Procedure

1. View the current vCPU scheduling configuration on the host.

```
# virsh schedinfo <vm_name>

Scheduler      : posix
cpu_shares     : 0
vcpu_period : 0
vcpu_quota : 0
emulator_period: 0
emulator_quota : 0
global_period  : 0
global_quota   : 0
iothread_period: 0
iothread_quota : 0
```

2. To configure an absolute vCPU cap for a VM, set the **vcpu_period** and **vcpu_quota** parameters. Both parameters use a numerical value that represents a time duration in microseconds.

   a. Set the **vcpu_period** parameter by using the **virsh schedinfo** command. For example:

   ```
   # virsh schedinfo <vm_name> --set vcpu_period=100000
   ```

   In this example, the **vcpu_period** is set to 100,000 microseconds, which means the scheduler enforces vCPU capping during this time interval.

   You can also use the **--live --config** options to configure a running VM without restarting it.

   b. Set the **vcpu_quota** parameter by using the **virsh schedinfo** command. For example:

```
# virsh schedinfo <vm_name> --set vcpu_quota=50000
```

In this example, the **vcpu_quota** is set to 50,000 microseconds, which specifies the maximum amount of CPU time that the VM can use during the **vcpu_period** time interval. In this case, **vcpu_quota** is set as the half of **vcpu_period**, so the VM can use up to 50% of the CPU time during that interval.

You can also use the **--live --config** options to configure a running VM without restarting it.

Verification

- Check that the vCPU scheduling parameters have the correct values.

```
# virsh schedinfo <vm_name>

Scheduler      : posix
cpu_shares     : 2048
vcpu_period    : 100000
vcpu_quota     : 50000
...
```

18.7.7. Tuning CPU weights

The *CPU weight* (or *CPU shares*) setting controls how much CPU time a virtual machine (VM) receives compared to other running VMs. By increasing the *CPU weight* of a specific VM, you can ensure that this VM gets more CPU time relative to other VMs. To prioritize CPU time allocation between multiple VMs, set the **cpu_shares** parameter

The possible CPU weight values range from *0* to *262144* and the default value for a new KVM VM is *1024*.

Procedure

1. Check the current *CPU weight* of a VM.

```
# virsh schedinfo <vm_name>

Scheduler      : posix
cpu_shares : 1024
vcpu_period    : 0
vcpu_quota     : 0
emulator_period: 0
emulator_quota : 0
global_period  : 0
global_quota   : 0
iothread_period: 0
iothread_quota : 0
```

2. Adjust the *CPU weight* to a preferred value.

```
# virsh schedinfo <vm_name> --set cpu_shares=2048

Scheduler      : posix
cpu_shares : 2048
```

```
vcpu_period    : 0
vcpu_quota     : 0
emulator_period: 0
emulator_quota : 0
global_period  : 0
global_quota   : 0
iothread_period: 0
iothread_quota : 0
```

In this example, **cpu_shares** is set to 2048. This means that if all other VMs have the value set to 1024, this VM gets approximately twice the amount of CPU time.

You can also use the **--live --config** options to configure a running VM without restarting it.

18.7.8. Enabling and disabling kernel same-page merging

Kernel Same-Page Merging (KSM) improves memory density by sharing identical memory pages between virtual machines (VMs). Therefore, enabling KSM might improve memory efficiency of your VM deployment.

However, enabling KSM also increases CPU utilization, and might negatively affect overall performance depending on the workload.

In RHEL 9 and later, KSM is disabled by default. To enable KSM and test its impact on your VM performance, see the following instructions.

Prerequisites

- Root access to your host system.

Procedure

1. Enable KSM:

   > **WARNING**
   >
   > Enabling KSM increases CPU utilization and affects overall CPU performance.

   a. Install the **ksmtuned** service:

   ```
   # {PackageManagerCommand} install ksmtuned
   ```

   b. Start the service:

   - To enable KSM for a single session, use the **systemctl** utility to start the **ksm** and **ksmtuned** services.

     ```
     # systemctl start ksm
     # systemctl start ksmtuned
     ```

▪

- To enable KSM persistently, use the **systemctl** utility to enable the **ksm** and **ksmtuned** services.

  ```
  # systemctl enable ksm
  Created symlink /etc/systemd/system/multi-user.target.wants/ksm.service →
  /usr/lib/systemd/system/ksm.service

  # systemctl enable ksmtuned
  Created symlink /etc/systemd/system/multi-user.target.wants/ksmtuned.service →
  /usr/lib/systemd/system/ksmtuned.service
  ```

2. Monitor the performance and resource consumption of VMs on your host to evaluate the benefits of activating KSM. Specifically, ensure that the additional CPU usage by KSM does not offset the memory improvements and does not cause additional performance issues. In latency-sensitive workloads, also pay attention to cross-NUMA page merges.

3. Optional: If KSM has not improved your VM performance, disable it:

   - To disable KSM for a single session, use the **systemctl** utility to stop **ksm** and **ksmtuned** services.

     ```
     # systemctl stop ksm
     # systemctl stop ksmtuned
     ```

   - To disable KSM persistently, use the **systemctl** utility to disable **ksm** and **ksmtuned** services.

     ```
     # systemctl disable ksm
     Removed /etc/systemd/system/multi-user.target.wants/ksm.service.
     # systemctl disable ksmtuned
     Removed /etc/systemd/system/multi-user.target.wants/ksmtuned.service.
     ```

NOTE

Memory pages shared between VMs before deactivating KSM will remain shared. To stop sharing, delete all the **PageKSM** pages in the system by using the following command:

```
# echo 2 > /sys/kernel/mm/ksm/run
```

However, this command increases memory usage, and might cause performance problems on your host or your VMs.

18.8. OPTIMIZING VIRTUAL MACHINE NETWORK PERFORMANCE

Due to the virtual nature of a VM’s network interface controller (NIC), the VM loses a portion of its allocated host network bandwidth, which can reduce the overall workload efficiency of the VM. The following tips can minimize the negative impact of virtualization on the virtual NIC (vNIC) throughput.

Procedure

Use any of the following methods and observe if it has a beneficial effect on your VM network performance:

Enable the vhost_net module

On the host, ensure the **vhost_net** kernel feature is enabled:

```
# lsmod | grep vhost
vhost_net              32768  1
vhost                 53248  1 vhost_net
tap                   24576  1 vhost_net
tun                   57344  6 vhost_net
```

If the output of this command is blank, enable the **vhost_net** kernel module:

```
# modprobe vhost_net
```

Set up multi-queue virtio-net

To set up the *multi-queue virtio-net* feature for a VM, use the **virsh edit** command to edit to the XML configuration of the VM. In the XML, add the following to the **<devices>** section, and replace **N** with the number of vCPUs in the VM, up to 16:

```
<interface type='network'>
      <source network='default'/>
      <model type='virtio'/>
      <driver name='vhost' queues='N'/>
</interface>
```

If the VM is running, restart it for the changes to take effect.

Batching network packets

In Linux VM configurations with a long transmission path, batching packets before submitting them to the kernel may improve cache utilization. To set up packet batching, use the following command on the host, and replace *tap0* with the name of the network interface that the VMs use:

```
# ethtool -C tap0 rx-frames 64
```

SR-IOV

If your host NIC supports SR-IOV, use SR-IOV device assignment for your vNICs. For more information, see Managing SR-IOV devices.

Additional resources

- Understanding virtual networking

18.9. VIRTUAL MACHINE PERFORMANCE MONITORING TOOLS

To identify what consumes the most VM resources and which aspect of VM performance needs optimization, performance diagnostic tools, both general and VM-specific, can be used.

Default OS performance monitoring tools

For standard performance evaluation, you can use the utilities provided by default by your host and guest operating systems:

- On your RHEL 9 host, as root, use the **top** utility or the **system monitor** application, and look for **qemu** and **virt** in the output. This shows how much host system resources your VMs are consuming.
  - If the monitoring tool displays that any of the **qemu** or **virt** processes consume a large portion of the host CPU or memory capacity, use the **perf** utility to investigate. For details, see below.
  - In addition, if a **vhost_net** thread process, named for example *vhost_net-1234*, is displayed as consuming an excessive amount of host CPU capacity, consider using virtual network optimization features, such as **multi-queue virtio-net**.
- On the guest operating system, use performance utilities and applications available on the system to evaluate which processes consume the most system resources.
  - On Linux systems, you can use the **top** utility.
  - On Windows systems, you can use the **Task Manager** application.

perf kvm

You can use the **perf** utility to collect and analyze virtualization-specific statistics about the performance of your RHEL 9 host. To do so:

1. On the host, install the *perf* package:

```
# dnf install perf
```

2. Use one of the **perf kvm stat** commands to display perf statistics for your virtualization host:
   - For real-time monitoring of your hypervisor, use the **perf kvm stat live** command.
   - To log the perf data of your hypervisor over a period of time, activate the logging by using the **perf kvm stat record** command. After the command is canceled or interrupted, the data is saved in the **perf.data.guest** file, which can be analyzed by using the **perf kvm stat report** command.

3. Analyze the **perf** output for types of **VM-EXIT** events and their distribution. For example, the **PAUSE_INSTRUCTION** events should be infrequent, but in the following output, the high occurrence of this event suggests that the host CPUs are not handling the running vCPUs well. In such a scenario, consider shutting down some of your active VMs, removing vCPUs from these VMs, or tuning the performance of the vCPUs.

```
# perf kvm stat report

Analyze events for all VMs, all VCPUs:


          VM-EXIT    Samples  Samples%     Time%    Min Time    Max Time         Avg time

 EXTERNAL_INTERRUPT     365634    31.59%    18.04%      0.42us  58780.59us
204.08us ( +-   0.99% )
         MSR_WRITE     293428    25.35%     0.13%      0.59us  17873.02us      1.80us ( +-
4.63% )
   PREEMPTION_TIMER     276162    23.86%     0.23%      0.51us  21396.03us      3.38us (
+-   5.19% )
```

```
  PAUSE_INSTRUCTION    189375   16.36%   11.75%     0.72us  29655.25us    256.77us
( +-   0.70% )
            HLT     20440    1.77%   69.83%     0.62us  79319.41us  14134.56us ( +-   0.79%
)
          VMCALL     12426    1.07%    0.03%     1.02us   5416.25us      8.77us ( +-   7.36%
)
     EXCEPTION_NMI       27    0.00%    0.00%     0.69us      1.34us      0.98us ( +-
3.50% )
     EPT_MISCONFIG        5    0.00%    0.00%     5.15us     10.85us      7.88us ( +-
11.67% )

Total Samples:1157497, Total events handled time:413728274.66us.
```

Other event types that can signal problems in the output of **perf kvm stat** include:

- **INSN_EMULATION** - suggests suboptimal VM I/O configuration.

For more information about using **perf** to monitor virtualization performance, see the **perf-kvm** man page on your system.

numastat

To see the current NUMA configuration of your system, you can use the **numastat** utility, which is provided by installing the **numactl** package.

The following shows a host with 4 running VMs, each obtaining memory from multiple NUMA nodes. This is not optimal for vCPU performance, and warrants adjusting:

```
# numastat -c qemu-kvm

Per-node process memory usage (in MBs)
PID              Node 0 Node 1 Node 2 Node 3 Node 4 Node 5 Node 6 Node 7 Total
---------------  ------ ------ ------ ------ ------ ------ ------ ------ -----
51722 (qemu-kvm)     68     16    357   6936      2      3    147    598  8128
51747 (qemu-kvm)    245     11      5     18   5172   2532      1     92  8076
53736 (qemu-kvm)     62    432   1661    506   4851    136     22    445  8116
53773 (qemu-kvm)   1393      3      1      2     12      0      0   6702  8114
---------------  ------ ------ ------ ------ ------ ------ ------ ------ -----
Total              1769    463   2024   7462  10037   2672    169   7837 32434
```

In contrast, the following shows memory being provided to each VM by a single node, which is significantly more efficient.

```
# numastat -c qemu-kvm

Per-node process memory usage (in MBs)
PID              Node 0 Node 1 Node 2 Node 3 Node 4 Node 5 Node 6 Node 7 Total
---------------  ------ ------ ------ ------ ------ ------ ------ ------ -----
51747 (qemu-kvm)      0      0      7      0   8072      0      1      0  8080
53736 (qemu-kvm)      0      0      7      0      0      0   8113      0  8120
53773 (qemu-kvm)      0      0      7      0      0      0      1   8110  8118
59065 (qemu-kvm)      0      0   8050      0      0      0      0      0  8051
---------------  ------ ------ ------ ------ ------ ------ ------ ------ -----
Total                 0      0   8072      0   8072      0   8114   8110 32368
```

18.10. ADDITIONAL RESOURCES

- Optimizing Windows virtual machines

CHAPTER 19. SECURING VIRTUAL MACHINES

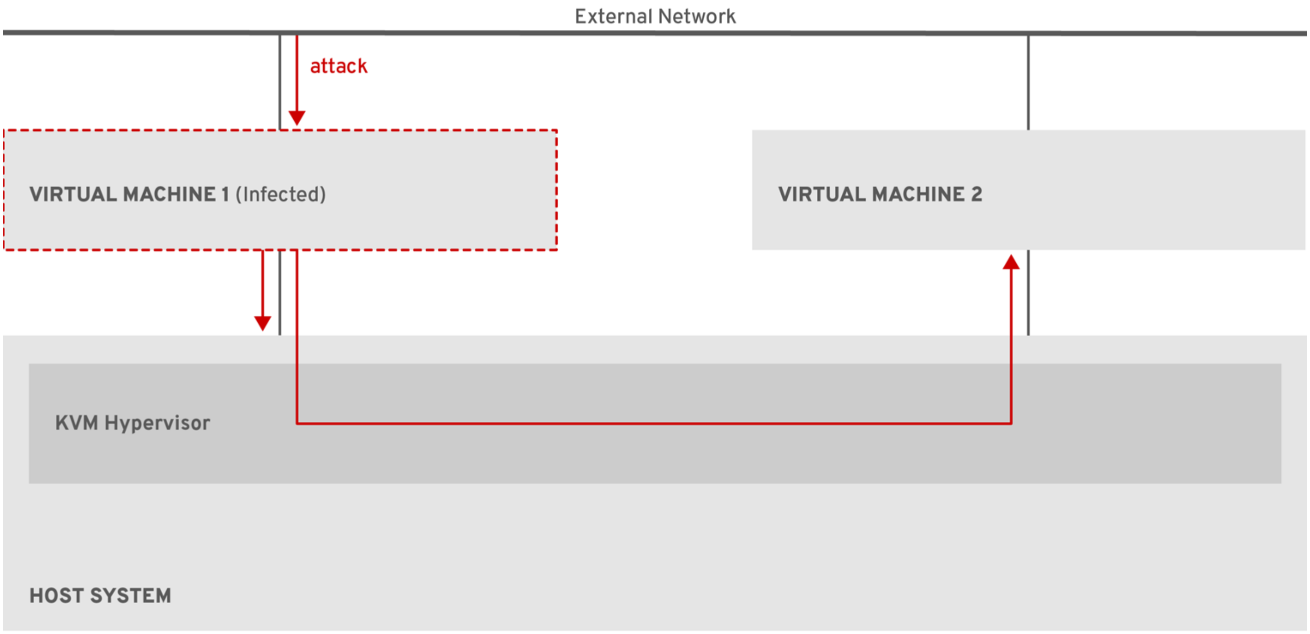
As an administrator of a RHEL 9 system with virtual machines (VMs), ensuring that your VMs are as secure as possible significantly lowers the risk of your guest and host OSs being infected by malicious software.

The following sections outline the mechanics of securing VMs on a RHEL 9 host and provides a list of methods to increase the security of your VMs.

19.1. HOW SECURITY WORKS IN VIRTUAL MACHINES

When using virtual machines (VMs), multiple operating systems can be housed within a single host machine. These systems are connected with the host through the hypervisor, and usually also through a virtual network. As a consequence, each VM can be used as a vector for attacking the host with malicious software, and the host can be used as a vector for attacking any of the VMs.

Figure 19.1. A potential malware attack vector on a virtualization host

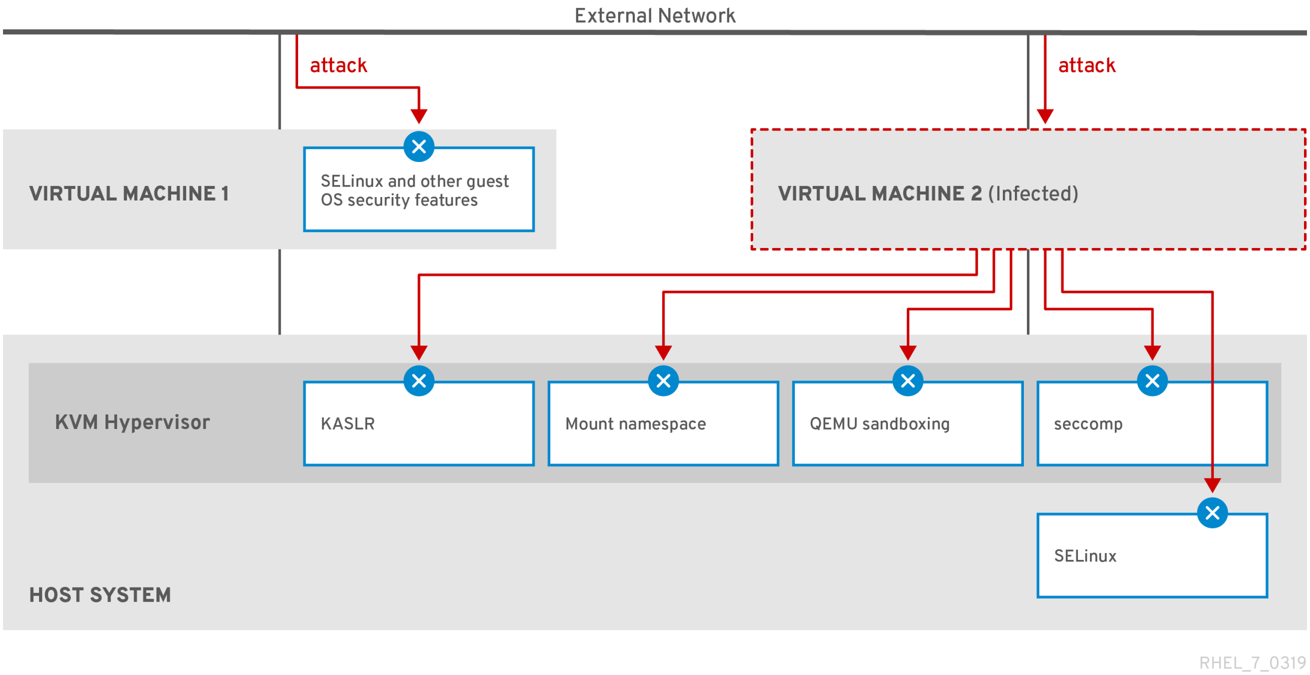


RHEL_7_0319

Because the hypervisor uses the host kernel to manage VMs, services running on the VM's operating system are frequently used for injecting malicious code into the host system. However, you can protect your system against such security threats by using a number of security features on your host and your guest systems.

These features, such as SELinux or QEMU sandboxing, provide various measures that make it more difficult for malicious code to attack the hypervisor and transfer between your host and your VMs.

Figure 19.2. Prevented malware attacks on a virtualization host



Many of the features that RHEL 9 provides for VM security are always active and do not have to be enabled or configured. For details, see Automatic features for virtual machine security.

In addition, you can adhere to a variety of best practices to minimize the vulnerability of your VMs and your hypervisor. For more information, see Best practices for securing virtual machines .

19.2. BEST PRACTICES FOR SECURING VIRTUAL MACHINES

Following the instructions below significantly decreases the risk of your virtual machines being infected with malicious code and used as attack vectors to infect your host system.

On the guest side:

- Secure the virtual machine as if it was a physical machine. The specific methods available to enhance security depend on the guest OS.
  If your VM is running RHEL 9, see Securing Red Hat Enterprise Linux 9 for detailed instructions on improving the security of your guest system.

On the host side:

- When managing VMs remotely, use cryptographic utilities such as **SSH** and network protocols such as **SSL** for connecting to the VMs.

- Ensure SELinux is in Enforcing mode:

  ```
  # getenforce
  Enforcing
  ```

  If SELinux is disabled or in *Permissive* mode, see the Using SELinux document for instructions on activating Enforcing mode.

NOTE

SELinux Enforcing mode also enables the sVirt RHEL 9 feature. This is a set of specialized SELinux booleans for virtualization, which can be manually adjusted for fine-grained VM security management.

- Use VMs with *SecureBoot*:
  SecureBoot is a feature that ensures that your VM is running a cryptographically signed OS. This prevents VMs whose OS has been altered by a malware attack from booting.

  SecureBoot can only be applied when installing a Linux VM that uses OVMF firmware on an AMD64 or Intel 64 host. For instructions, see Creating a SecureBoot virtual machine.

- Do not use **qemu-*** commands, such as **qemu-kvm**.
  QEMU is an essential component of the virtualization architecture in RHEL 9, but it is difficult to manage manually, and improper QEMU configurations may cause security vulnerabilities. Therefore, using most **qemu-*** commands is not supported by Red Hat. Instead, use *libvirt* utilities, such as **virsh**, **virt-install**, and **virt-xml**, as these orchestrate QEMU according to the best practices.

  Note, however, that the **qemu-img** utility is supported for management of virtual disk images.

Additional resources

- SELinux booleans for virtualization in RHEL

19.3. AUTOMATIC FEATURES FOR VIRTUAL MACHINE SECURITY

In addition to manual means of improving the security of your virtual machines listed in Best practices for securing virtual machines, a number of security features are provided by the **libvirt** software suite and are automatically enabled when using virtualization in RHEL 9. These include:

System and session connections

To access all the available utilities for virtual machine management in RHEL 9, you need to use the *system connection* of libvirt (**qemu:///system**). To do so, you must have root privileges on the system or be a part of the *libvirt* user group.
Non-root users that are not in the *libvirt* group can only access a *session connection* of libvirt (**qemu:///session**), which has to respect the access rights of the local user when accessing resources. For example, using the session connection, you cannot detect or access VMs created in the system connection or by other users. Also, available VM networking configuration options are significantly limited.

NOTE

The RHEL 9 documentation assumes you have system connection privileges.

Virtual machine separation

Individual VMs run as isolated processes on the host, and rely on security enforced by the host kernel. Therefore, a VM cannot read or access the memory or storage of other VMs on the same host.

QEMU sandboxing

A feature that prevents QEMU code from executing system calls that can compromise the security of the host.

Kernel Address Space Randomization (KASLR)

Enables randomizing the physical and virtual addresses at which the kernel image is decompressed. Thus, KASLR prevents guest security exploits based on the location of kernel objects.

19.4. CREATING A SECUREBOOT VIRTUAL MACHINE

You can create a Linux virtual machine (VM) that uses the *SecureBoot* feature, which ensures that your VM is running a cryptographically signed OS. This can be useful if the guest OS of a VM has been altered by malware. In such a scenario, SecureBoot prevents the VM from booting, which stops the potential spread of the malware to your host machine.

Prerequisites

- The VM is the Q35 machine type.
- Your host system uses the AMD64 or Intel 64 architecture.
- The **edk2-OVMF** packages is installed:

  ```
  # dnf install edk2-ovmf
  ```

- An operating system (OS) installation source is available locally or on a network. This can be one of the following formats:
  - An ISO image of an installation medium
  - A disk image of an existing VM installation

  > **WARNING**
  >
  > Installing from a host CD-ROM or DVD-ROM device is not possible in RHEL 9. If you select a CD-ROM or DVD-ROM as the installation source when using any VM installation method available in RHEL 9, the installation will fail. For more information, see the Red Hat Knowledgebase solution RHEL 7 or higher can't install guest OS from CD/DVD-ROM.

- Optional: A Kickstart file can be provided for faster and easier configuration of the installation.

Procedure

1. Use the **virt-install** command to create a VM as detailed in Creating virtual machines by using the command line. For the **--boot** option, use the **uefi,nvram_template=/usr/share/OVMF/OVMF_VARS.secboot.fd** value. This uses the **OVMF_VARS.secboot.fd** and **OVMF_CODE.secboot.fd** files as templates for the VM's non-volatile RAM (NVRAM) settings, which enables the SecureBoot feature.
   For example:

   ```
   # virt-install --name rhel8sb --memory 4096 --vcpus 4 --os-variant rhel9.0 --boot
   ```

```
uefi,nvram_template=/usr/share/OVMF/OVMF_VARS.secboot.fd --disk
boot_order=2,size=10 --disk boot_order=1,device=cdrom,bus=scsi,path=/images/RHEL-9.0-
installation.iso
```

2. Follow the OS installation procedure according to the instructions on the screen.

Verification

1. After the guest OS is installed, access the VM's command line by opening the terminal in the graphical guest console or connecting to the guest OS using SSH.

2. To confirm that SecureBoot has been enabled on the VM, use the **mokutil --sb-state** command:

```
# mokutil --sb-state
SecureBoot enabled
```

Additional resources

Manually installing Red Hat Enterprise Linux

19.5. LIMITING WHAT ACTIONS ARE AVAILABLE TO VIRTUAL MACHINE USERS

In some cases, actions that users of virtual machines (VMs) hosted on RHEL 9 can perform by default may pose a security risk. If that is the case, you can limit the actions available to VM users by configuring the **libvirt** daemons to use the **polkit** policy toolkit on the host machine.

Procedure

1. Optional: Ensure your system's **polkit** control policies related to **libvirt** are set up according to your preferences.

   a. Find all libvirt-related files in the **/usr/share/polkit-1/actions/** and **/usr/share/polkit-1/rules.d/** directories.

   ```
   # ls /usr/share/polkit-1/actions | grep libvirt
   # ls /usr/share/polkit-1/rules.d | grep libvirt
   ```

   b. Open the files and review the rule settings.
   For information about reading the syntax of **polkit** control policies, use **man polkit**.

   c. Modify the **libvirt** control policies. To do so:

      i. Create a new **.rules** file in the **/etc/polkit-1/rules.d/** directory.

      ii. Add your custom policies to this file, and save it.
      For further information and examples of **libvirt** control policies, see the **libvirt** upstream documentation.

2. Configure your VMs to use access policies determined by **polkit**.
To do so, find all configuration files for virtualization drivers in the **/etc/libvirt/** directory, and uncomment the **access_drivers = ["polkit"]** line in them.

```
# find /etc/libvirt/ -name virt*d.conf -exec sed -i 's/#access_drivers = \[ "polkit"
\]/access_drivers = \[ "polkit" \]/g' {} +
```

3. For each file that you modified in the previous step, restart the corresponding service.
   For example, if you have modified **/etc/libvirt/virtqemud.conf**, restart the **virtqemud** service.

   ```
   # systemctl try-restart virtqemud
   ```

Verification

- As a user whose VM actions you intended to limit, perform one of the restricted actions.
  For example, if unprivileged users are restricted from viewing VMs created in the system session:

  ```
  $ virsh -c qemu:///system list --all
  Id   Name           State
  -------------------------------
  ```

  If this command does not list any VMs even though one or more VMs exist on your system, **polkit** successfully restricts the action for unprivileged users.

Troubleshooting

- Currently, configuring **libvirt** to use **polkit** makes it impossible to connect to VMs using the RHEL 9 web console, due to an incompatibility with the **libvirt-dbus** service.
  If you require fine-grained access control of VMs in the web console, create a custom D-Bus policy. For more information, see the Red Hat Knowledgebase solution How to configure fine-grained control of Virtual Machines in Cockpit.

Additional resources

- The **man polkit** command
- The **libvirt** upstream information about polkit access control policies

19.6. CONFIGURING VNC PASSWORDS

To manage access to the graphical output of a virtual machine (VM), you can configure a password for the VNC console of the VM.

With a VNC password configured on a VM, users of the VMs must enter the password when attempting to view or interact with the VNC graphical console of the VMs, for example by using the **virt-viewer** utility.

> **IMPORTANT**
>
> VNC passwords are not a sufficient measure for ensuring the security of a VM environment. For details, see QEMU documentation on VNC security.
>
> In addition, the VNC password is saved in plain text in the configuration of the VM, so for the password to be effective, the user must not be able to display the VM configuration.

Prerequisites

- The VM that you want to protect with a VNC password has VNC graphics configured.
  To ensure that this is the case, use the **virsh dumpxml** command as follows:

  ```
  # virsh dumpxml <vm-name> | grep graphics

   <graphics type='vnc' ports='-1' autoport=yes listen=127.0.0.1>
   </graphics>
  ```

Procedure

1. Open the configuration of the VM that you want to assign a VNC password to.

   ```
   # virsh edit <vm-name>
   ```

2. On the **<graphics>** line of the configuration, add the **passwd** attribute and the password string. The password must be 8 characters or fewer.

   ```
    <graphics type='vnc' ports='-1' autoport=yes listen=127.0.0.1 passwd='<password>'>
   ```

   - Optional: In addition, define a date and time when the password will expire.

     ```
      <graphics type='vnc' ports='-1' autoport=yes listen=127.0.0.1 passwd='<password>'
     passwdValidTo='2025-02-01T15:30:00'>
     ```

     In this example, the password will expire on February 1st 2025, at 15:30 UTC.

3. Save the configuration.

Verification

1. Start the modified VM.

   ```
   # virsh start <vm-name>
   ```

2. Open a graphical console of the VM, for example by using the **virt-viewer** utility:

   ```
   # virt-viewer <vm-name>
   ```

   If the VNC password has been configured properly, a dialogue window appears that requests you to enter the password.

19.7. SELINUX BOOLEANS FOR VIRTUALIZATION

RHEL 9 provides the **sVirt** feature, which is a set of specialized SELinux booleans that are automatically enabled on a host with SELinux in Enforcing mode.

For fine-grained configuration of virtual machines security on a RHEL 9 system, you can configure SELinux booleans on the host to ensure the hypervisor acts in a specific way.

To list all virtualization-related booleans and their statuses, use the **getsebool -a | grep virt** command:

```
$ getsebool -a | grep virt
[...]
virt_sandbox_use_netlink --> off
virt_sandbox_use_sys_admin --> off
virt_transition_userdomain --> off
virt_use_comm --> off
virt_use_execmem --> off
virt_use_fusefs --> off
[...]
```

To enable a specific boolean, use the **setsebool -P *boolean_name* on** command as root. To disable a boolean, use **setsebool -P *boolean_name* off**.

The following table lists virtualization-related booleans available in RHEL 9 and what they do when enabled:

Table 19.1. SELinux virtualization booleans

SELinux Boolean	Description
staff_use_svirt	Enables non-root users to create and transition VMs to sVirt.
unprivuser_use_svirt	Enables unprivileged users to create and transition VMs to sVirt.
virt_sandbox_use_audit	Enables sandbox containers to send audit messages.
virt_sandbox_use_netlink	Enables sandbox containers to use netlink system calls.
virt_sandbox_use_sys_admin	Enables sandbox containers to use sys_admin system calls, such as mount.
virt_transition_userdomain	Enables virtual processes to run as user domains.
virt_use_comm	Enables virt to use serial/parallel communication ports.
virt_use_execmem	Enables confined virtual guests to use executable memory and executable stack.
virt_use_fusefs	Enables virt to read FUSE mounted files.
virt_use_nfs	Enables virt to manage NFS mounted files.
virt_use_rawip	Enables virt to interact with rawip sockets.
virt_use_samba	Enables virt to manage CIFS mounted files.

SELinux Boolean	Description
virt_use_sanlock	Enables confined virtual guests to interact with the sanlock.
virt_use_usb	Enables virt to use USB devices.
virt_use_xserver	Enables virtual machine to interact with the X Window System.

19.8. SETTING UP IBM SECURE EXECUTION ON IBM Z

When using IBM Z hardware to run a RHEL 9 host, you can improve the security of your virtual machines (VMs) by configuring the IBM Secure Execution feature for the VMs.

IBM Secure Execution, also known as Protected Virtualization, prevents the host system from accessing a VM's state and memory contents. As a result, even if the host is compromised, it cannot be used as a vector for attacking the guest operating system. In addition, Secure Execution can be used to prevent untrusted hosts from obtaining sensitive information from the VM.

You can convert an existing VM on an IBM Z host into a secured VM by enabling IBM Secure Execution.

IMPORTANT

For securing production environments, consult the IBM documentation on fully securing workloads with Secure Execution, which explains how to further secure your workloads.

Prerequisites

- The system hardware is one of the following:
  - IBM z15 or later
  - IBM LinuxONE III or later
- The Secure Execution feature is enabled for your system. To verify, use:

  ```
  # grep facilities /proc/cpuinfo | grep 158
  ```

  If this command displays any output, your CPU is compatible with Secure Execution.
- The kernel includes support for Secure Execution. To confirm, use:

  ```
  # ls /sys/firmware | grep uv
  ```

  If the command generates any output, your kernel supports Secure Execution.
- The host CPU model contains the **unpack** facility. To confirm, use:

  ```
  # virsh domcapabilities | grep unpack
  <feature policy='require' name='unpack'/>
  ```

If the command generates the above output, your CPU host model is compatible with Secure Execution.

- The CPU mode of the VM is set to **host-model**.

  ```
  # virsh dumpxml <vm_name> | grep "<cpu mode='host-model'/>"
  ```

  If the command generates any output, the VM's CPU mode is set correctly.

- The *genprotimg* package must be installed on the host.

  ```
  # dnf install genprotimg
  ```

- The **guestfs-tools** package is installed on the host in case you want to modify the VM image directly from the host.

  ```
  # dnf install guestfs-tools
  ```

- You have obtained and verified the IBM Z host key document. For details, see Verifying the host key document in IBM documentation.

Procedure

Do the following steps **on your host**:

1. Add the **prot_virt=1** kernel parameter to the boot configuration of the host.

   ```
   # grubby --update-kernel=ALL --args="prot_virt=1"
   ```

2. Update the boot menu:
   # zipl

3. Use **virsh edit** to modify the XML configuration of the VM you want to secure.

4. Add **<launchSecurity type="s390-pv"/>** to the under the **</devices>** line. For example:

   ```
   [...]
       </memballoon>
     </devices>
     <launchSecurity type="s390-pv"/>
   </domain>
   ```

5. If the **<devices>** section of the configuration includes a **virtio-rng** device (**<rng model="virtio">**), remove all lines of the **<rng> </rng>** block.

6. Optional: If the VM that you want to secure is using 32 GiB of RAM or more, add the **<async-teardown enabled='yes'/>** line to the **<features></features>** section in its XML configuration. This improves the performance of rebooting or stopping such Secure Execution guests.

Proceed with the steps in one of the following sections. You can either log in to the guest and configure it manually for Secure Execution or configure the guest image directly from the host by using a script and **guestfs-tools**.

Manually configuring the VM for Secure Execution

Do the following steps **in the guest operating system**of the VM you want to secure.

1. Create a parameter file. For example:

   ```
   # touch ~/secure-parameters
   ```

2. In the **/boot/loader/entries** directory, identify the boot loader entry with the latest version:

   ```
   # ls /boot/loader/entries -l
   [...]
   -rw-r--r--. 1 root root  281 Oct  9 15:51 3ab27a195c2849429927b00679db15c1-4.18.0-
   240.el8.s390x.conf
   ```

3. Retrieve the kernel options line of the boot loader entry:

   ```
   # cat /boot/loader/entries/3ab27a195c2849429927b00679db15c1-4.18.0-240.el8.s390x.conf
   | grep options
   options root=/dev/mapper/rhel-root
   rd.lvm.lv=rhel/root rd.lvm.lv=rhel/swap
   ```

4. Add the content of the options line and **swiotlb=262144** to the created parameters file.

   ```
   # echo "root=/dev/mapper/rhel-root rd.lvm.lv=rhel/root rd.lvm.lv=rhel/swap swiotlb=262144" >
   ~/secure-parameters
   ```

5. Generate a new IBM Secure Execution image.
   For example, the following creates a **/boot/secure-image** secured image based on the **/boot/vmlinuz-4.18.0-240.el8.s390x** image, using the **secure-parameters** file, the **/boot/initramfs-4.18.0-240.el8.s390x.img** initial RAM disk file, and the **HKD-8651-000201C048.crt** host key document.

   ```
   # genprotimg -i /boot/vmlinuz-4.18.0-240.el8.s390x -r /boot/initramfs-4.18.0-
   240.el8.s390x.img -p ~/secure-parameters -k HKD-8651-00020089A8.crt -o /boot/secure-
   image
   ```

   By using the **genprotimg** utility creates the secure image, which contains the kernel parameters, initial RAM disk, and boot image.

6. Update the VM's boot menu to boot from the secure image. In addition, remove the lines starting with **initrd** and **options**, as they are not needed.
   For example, in a RHEL 8.3 VM, the boot menu can be edited in the **/boot/loader/entries/** directory:

   ```
   # cat /boot/loader/entries/3ab27a195c2849429927b00679db15c1-4.18.0-240.el8.s390x.conf
   title Red Hat Enterprise Linux 8.3
   version 4.18.0-240.el8.s390x
   linux /boot/secure-image
   [...]
   ```

7. Create the bootable disk image:

   ```
   # zipl -V
   ```

8. Securely remove the original unprotected files. For example:

```
# shred /boot/vmlinuz-4.18.0-240.el8.s390x
# shred /boot/initramfs-4.18.0-240.el8.s390x.img
# shred secure-parameters
```

The original boot image, the initial RAM image, and the kernel parameter file are unprotected, and if they are not removed, VMs with Secure Execution enabled can still be vulnerable to hacking attempts or sensitive data mining.

Configuring the VM for Secure Execution directly from the host

You can use **guestfs-tools** to modify an existing image without manually booting it. However, use the following examples only in testing and development environments. For securing production environments, see the IBM documentation on fully securing workloads with Secure Execution .

Do the following steps **on the host**.

1. Create a script that contains the host key document and that configures the existing VM to use Secure Execution. For example:

```
#!/usr/bin/bash

echo "$(cat /proc/cmdline) swiotlb=262144" > parmfile

cat > ./HKD.crt << EOF
-----BEGIN CERTIFICATE-----
1234569901234569901234569901234569901234569901234569901234569900
1234569901234569901234569901234569901234569901234569901234569900
1234569901234569901234569901234569901234569901234569901234569900
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1234569901234569901234569901234569901234569901234569901234569900
1234569901234569901234569901234569901234569901234569901234569900
xLPRGYwhmXzKDg==
-----END CERTIFICATE-----
EOF
```

```
version=$(uname -r)

kernel=/boot/vmlinuz-$version
initrd=/boot/initramfs-$version.img

genprotimg -k ./HKD.crt -p ./parmfile -i $kernel -r $initrd -o /boot/secure-linux --no-verify

cat >> /etc/zipl.conf<< EOF

[secure]
target=/boot
image=/boot/secure-linux
EOF

zipl -V

shutdown -h now
```

2. Ensure the VM is shut-down.

3. Add the script to the existing VM image by using **guestfs-tools** and mark it to *run on first boot*.

```
# virt-customize -a <vm_image_path> --selinux-relabel --firstboot <script_path>
```

4. Boot the VM from the image with the added script.
   The script runs on first boot, and then shuts down the VM again. As a result, the VM is now configured to run with Secure Execution on the host that has the corresponding host key.

Verification

- On the host, use the **virsh dumpxml** utility to confirm the XML configuration of the secured VM. The configuration must include the **<launchSecurity type="s390-pv"/>** element, and no <rng model="virtio"> lines.

```
# virsh dumpxml vm-name
[...]
  <cpu mode='host-model'/>
  <devices>
    <disk type='file' device='disk'>
      <driver name='qemu' type='qcow2' cache='none' io='native'>
      <source file='/var/lib/libvirt/images/secure-guest.qcow2'/>
      <target dev='vda' bus='virtio'/>
    </disk>
    <interface type='network'>
      <source network='default'/>
      <model type='virtio'/>
    </interface>
    <console type='pty'/>
    <memballoon model='none'/>
  </devices>
  <launchSecurity type="s390-pv"/>
</domain>
```

Additional resources

- IBM documentation for Secure Execution on Linux
- IBM documentation on fully securing workloads with Secure Execution
- IBM documentation on **genprotimg**
- Configuring kernel command-line parameters

19.9. ATTACHING CRYPTOGRAPHIC COPROCESSORS TO VIRTUAL MACHINES ON IBM Z

To use hardware encryption in your virtual machine (VM) on an IBM Z host, create mediated devices from a cryptographic coprocessor device and assign them to the intended VMs. For detailed instructions, see below.

Prerequisites

- Your host is running on IBM Z hardware.
- The cryptographic coprocessor is compatible with device assignment. To confirm this, ensure that the **type** of your coprocessor is listed as **CEX4** or later.

```
# lszcrypt -V

CARD.DOMAIN TYPE  MODE        STATUS  REQUESTS  PENDING HWTYPE QDEPTH
FUNCTIONS  DRIVER
--------------------------------------------------------------------------------------------
05         CEX5C CCA-Coproc  online        1        0     11     08 S--D--N--  cex4card
05.0004    CEX5C CCA-Coproc  online        1        0     11     08 S--D--N--  cex4queue
05.00ab    CEX5C CCA-Coproc  online        1        0     11     08 S--D--N--  cex4queue
```

- The **vfio_ap** kernel module is loaded. To verify, use:

```
# lsmod | grep vfio_ap
vfio_ap         24576  0
[...]
```

  To load the module, use:

```
# modprobe vfio_ap
```

- The **s390utils** version supports **ap** handling:

```
# lszdev --list-types
...
ap           Cryptographic Adjunct Processor (AP) device
...
```

Procedure

1. Obtain the decimal values for the devices that you want to assign to the VM. For example, for the devices **05.0004** and **05.00ab**:

```
# echo "obase=10; ibase=16; 04" | bc
4
# echo "obase=10; ibase=16; AB" | bc
171
```

2. On the host, reassign the devices to the **vfio-ap** drivers:

```
# chzdev -t ap apmask=-5 aqmask=-4,-171
```

NOTE

To assign the devices persistently, use the **-p** flag.

3. Verify that the cryptographic devices have been reassigned correctly.

```
# lszcrypt -V

CARD.DOMAIN TYPE  MODE        STATUS  REQUESTS  PENDING HWTYPE QDEPTH
FUNCTIONS  DRIVER
-----------------------------------------------------------------------------------------
05          CEX5C CCA-Coproc  -              1        0     11     08 S--D--N--  cex4card
05.0004     CEX5C CCA-Coproc  -              1        0     11     08 S--D--N--  vfio_ap
05.00ab     CEX5C CCA-Coproc  -              1        0     11     08 S--D--N--  vfio_ap
```

If the DRIVER values of the domain queues changed to **vfio_ap**, the reassignment succeeded.

4. Create an XML snippet that defines a new mediated device.
The following example shows defining a persistent mediated device and assigning queues to it. Specifically, the **vfio_ap.xml** XML snippet in this example assigns a domain adapter **0x05**, domain queues **0x0004** and **0x00ab**, and a control domain **0x00ab** to the mediated device.

```
# vim vfio_ap.xml

<device>
  <parent>ap_matrix</parent>
  <capability type="mdev">
    <type id="vfio_ap-passthrough"/>
    <attr name='assign_adapter' value='0x05'/>
    <attr name='assign_domain' value='0x0004'/>
    <attr name='assign_domain' value='0x00ab'/>
    <attr name='assign_control_domain' value='0x00ab'/>
  </capability>
</device>
```

5. Create a new mediated device from the **vfio_ap.xml** XML snippet.

```
# virsh nodedev-define vfio_ap.xml
Node device 'mdev_8f9c4a73_1411_48d2_895d_34db9ac18f85_matrix' defined from
'vfio_ap.xml'
```

6. Start the mediated device that you created in the previous step, in this case **mdev_8f9c4a73_1411_48d2_895d_34db9ac18f85_matrix**.

```
# virsh nodedev-start mdev_8f9c4a73_1411_48d2_895d_34db9ac18f85_matrix
Device mdev_8f9c4a73_1411_48d2_895d_34db9ac18f85_matrix started
```

7. Check that the configuration has been applied correctly

```
# cat /sys/devices/vfio_ap/matrix/mdev_supported_types/vfio_ap-passthrough/devices/669d9b23-fe1b-4ecb-be08-a2fabca99b71/matrix
05.0004
05.00ab
```

If the output contains the numerical values of queues that you have previously assigned to **vfio-ap**, the process was successful.

8. Attach the mediated device to the VM.

   a. Display the UUID of the mediated device that you created and save it for the next step.

   ```
   # virsh nodedev-dumpxml mdev_8f9c4a73_1411_48d2_895d_34db9ac18f85_matrix

   <device>
     <name>mdev_8f9c4a73_1411_48d2_895d_34db9ac18f85_matrix</name>
     <parent>ap_matrix</parent>
     <capability type='mdev'>
       <type id='vfio_ap-passthrough'/>
       <uuid>8f9c4a73-1411-48d2-895d-34db9ac18f85</uuid>
       <iommuGroup number='0'/>
       <attr name='assign_adapter' value='0x05'/>
       <attr name='assign_domain' value='0x0004'/>
       <attr name='assign_domain' value='0x00ab'/>
       <attr name='assign_control_domain' value='0x00ab'/>
     </capability>
   </device>
   ```

   b. Create and open an XML file for the cryptographic card mediated device. For example:

   ```
   # vim crypto-dev.xml
   ```

   c. Add the following lines to the file and save it. Replace the **uuid** value with the UUID you obtained in step *a*.

   ```
   <hostdev mode='subsystem' type='mdev' managed='no' model='vfio-ap'>
     <source>
       <address uuid='8f9c4a73-1411-48d2-895d-34db9ac18f85'/>
     </source>
   </hostdev>
   ```

   d. Use the XML file to attach the mediated device to the VM. For example, to permanently attach a device defined in the **crypto-dev.xml** file to the running **testguest1** VM:

   ```
   # virsh attach-device testguest1 crypto-dev.xml --live --config
   ```

   The **--live** option attaches the device to a running VM only, without persistence between boots. The **--config** option makes the configuration changes persistent. You can use the **--config** option alone to attach the device to a shut-down VM.

Note that each UUID can only be assigned to one VM at a time.

Verification

1. Ensure that the guest operating system detects the assigned cryptographic devices.

```
# lszcrypt -V

CARD.DOMAIN TYPE  MODE        STATUS  REQUESTS  PENDING HWTYPE QDEPTH
FUNCTIONS  DRIVER
--------------------------------------------------------------------------------------------
05         CEX5C CCA-Coproc  online        1        0     11     08 S--D--N--  cex4card
05.0004    CEX5C CCA-Coproc  online        1        0     11     08 S--D--N--  cex4queue
05.00ab    CEX5C CCA-Coproc  online        1        0     11     08 S--D--N--  cex4queue
```

The output of this command in the guest operating system will be identical to that on a host logical partition with the same cryptographic coprocessor devices available.

2. In the guest operating system, confirm that a control domain has been successfully assigned to the cryptographic devices.

```
# lszcrypt -d C

DOMAIN 00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f
------------------------------------------------------
   00  . . . . U . . . . . . . . . . .
   10  . . . . . . . . . . . . . . . .
   20  . . . . . . . . . . . . . . . .
   30  . . . . . . . . . . . . . . . .
   40  . . . . . . . . . . . . . . . .
   50  . . . . . . . . . . . . . . . .
   60  . . . . . . . . . . . . . . . .
   70  . . . . . . . . . . . . . . . .
   80  . . . . . . . . . . . . . . . .
   90  . . . . . . . . . . . . . . . .
   a0  . . . . . . . . . . . B . . . .
   b0  . . . . . . . . . . . . . . . .
   c0  . . . . . . . . . . . . . . . .
   d0  . . . . . . . . . . . . . . . .
   e0  . . . . . . . . . . . . . . . .
   f0  . . . . . . . . . . . . . . . .
------------------------------------------------------
C: Control domain
U: Usage domain
B: Both (Control + Usage domain)
```

If **lszcrypt -d C** displays **U** and **B** intersections in the cryptographic device matrix, the control domain assignment was successful.

19.10. ENABLING STANDARD HARDWARE SECURITY ON WINDOWS VIRTUAL MACHINES

To secure Windows virtual machines (VMs), you can enable basic level security by using the standard hardware capabilities of the Windows device.

Prerequisites

- Make sure you have installed the latest WHQL certified VirtIO drivers.
- Make sure the VM's firmware supports UEFI boot.
- Install the **edk2-OVMF** package on your host machine.

  ```
  # {PackageManagerCommand} install edk2-ovmf
  ```

- Install the **vTPM** packages on your host machine.

  ```
  # {PackageManagerCommand} install swtpm libtpms
  ```

- Make sure the VM is using the Q35 machine architecture.
- Make sure you have the Windows installation media.

Procedure

1. Enable TPM 2.0 by adding the following parameters to the **<devices>** section in the VM's XML configuration.

   ```
   <devices>
   [...]
     <tpm model='tpm-crb'>
       <backend type='emulator' version='2.0'/>
     </tpm>
   [...]
   </devices>
   ```

2. Install Windows in UEFI mode. For more information about how to do so, see Creating a SecureBoot virtual machine.
3. Install the VirtIO drivers on the Windows VM. For more information about how to do so, see Installing virtio drivers on a Windows guest .
4. In UEFI, enable Secure Boot. For more information about how to do so, see Secure Boot.

Verification

- Ensure that the **Device Security** page on your Windows machine displays the following message:
  Settings > Update & Security > Windows Security > Device Security

  ```
  Your device meets the requirements for standard hardware security.
  ```

19.11. ENABLING ENHANCED HARDWARE SECURITY ON WINDOWS VIRTUAL MACHINES

To further secure Windows virtual machines (VMs), you can enable virtualization-based protection of code integrity, also known as Hypervisor-Protected Code Integrity (HVCI).

Prerequisites

- You have RHEL 9.6 or later as your host.
- You have enabled standard hardware security. For more information, see Enabling standard hardware security on Windows virtual machines.
- You have enabled Hyper-V enlightenments. For more information, see Enabling Hyper-V enlightenments.

Procedure

1. Open the XML configuration of the Windows VM. The following example opens the configuration of the *Example-L1* VM:

   ```
   # virsh edit Example-L1
   ```

2. Under the **<cpu>** section, specify the CPU mode and add the policy flag.

   #### IMPORTANT

   - For Intel CPUs, enable the **vmx** policy flag.
   - For AMD CPUs, enable the **svm** policy flag.
   - If you do not wish to specify a custom CPU, you can set the **<cpu mode>** as **host-passthrough**.

   ```
   <cpu mode='custom' match='exact' check='partial'>
     <model fallback='allow'>Skylake-Client-IBRS</model>
     <topology sockets='1' dies='1' cores='4' threads='1'/>
     <feature policy='require' name='vmx'/>
   </cpu>
   ```

3. Save the XML configuration and reboot the VM.
4. On the VMs operating system, navigate to the **Core isolation details** page: **Settings > Update & Security > Windows Security > Device Security > Core isolation details**
5. Toggle the switch to enable **Memory Integrity**.
6. Reboot the VM.

NOTE

For other methods of enabling HVCI, see the relevant Microsoft documentation.

Verification

- Ensure that the **Device Security** page on your Windows VM displays the following message: **Settings > Update & Security > Windows Security > Device Security**

  ```
  Your device meets the requirements for enhanced hardware security.
  ```

- Alternatively, check System Information about the Windows VM:
  a. Run **msinfo32.exe** in a command prompt.
  b. Check if **Credential Guard, Hypervisor enforced Code Integrity** is listed under **Virtualization-based security Services Running**

19.12. ENABLING SEV-SNP

Secure Encrypted Virtualization-Secure Nested Paging (SEV-SNP) is a hardware-based security feature that provides strong memory encryption and integrity protection for virtual machines (VMs). This isolates VMs from the hypervisor and other host system software. SEV-SNP is available only with AMD CPUs.

IMPORTANT

Enabling SEV-SNP on a RHEL host is a Technology Preview only. However, enabling SEV-SNP on a RHEL guest is fully supported.

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

19.12.1. Enabling SEV-SNP on a RHEL host

To enable Secure Encrypted Virtualization-Secure Nested Paging (SEV-SNP) on a RHEL host, you must ensure that your system meets the prerequisites and then install the **snphost** and **libvirt-daemon-kvm** packages.

SEV-SNP is a hardware-based security feature that provides strong memory encryption and integrity protection for virtual machines (VMs). This isolates VMs from the hypervisor and other host system software. SEV-SNP is available only with AMD CPUs.

IMPORTANT

Using SEV-SNP on a RHEL host is a Technology Preview only. Technology Preview features are not supported with Red Hat production service levels 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

- Your host uses the following hardware and software:
  - An AMD CPU that supports SEV-SNP, such as a supported model from the AMD EPYC series
  - RHEL 9.4 or later
  - SEV firmware version 1.55 or later
  - Sufficient system memory for SNP Memory Coverage configuration

- The following settings are enabled in UEFI CPU menu:
  - **SVM Mode** (Secure Virtual Machine Mode)
  - **SEV-SNP Support** or **Secure Nested Paging**
  - **SMEE** (Secure Memory Encryption)

Procedure

- Install the necessary packages on the RHEL host.

```
# dnf install snphost libvirt-daemon-kvm
```

Verification

- Verify that SEV-SNP is enabled on the host.

```
# virt-host-validate qemu

 QEMU: Checking for hardware virtualization:   PASS
 QEMU: Checking if device '/dev/kvm' exists:   PASS
 QEMU: Checking if device '/dev/kvm' is accessible:   PASS
 QEMU: Checking if device '/dev/vhost-net' exists:   PASS
 QEMU: Checking if device '/dev/net/tun' exists:   PASS
 QEMU: Checking for cgroup 'cpu' controller support:   PASS
 QEMU: Checking for cgroup 'cpuacct' controller support:   PASS
 QEMU: Checking for cgroup 'cpuset' controller support:   PASS
 QEMU: Checking for cgroup 'memory' controller support:   PASS
 QEMU: Checking for cgroup 'devices' controller support:   PASS
 QEMU: Checking for cgroup 'blkio' controller support:   PASS
 QEMU: Checking for device assignment IOMMU support:   PASS
 QEMU: Checking if IOMMU is enabled by kernel:   PASS
 QEMU: Checking for secure guest support:   PASS
```

If SEV-SNP is enabled on the host, the **Checking for secure guest support** line reports **PASS**.

Next steps

- Configure SEV-SNP on a RHEL guest

19.12.2. Enabling SEV-SNP on a RHEL guest

To enable Secure Encrypted Virtualization-Secure Nested Paging (SEV-SNP) in a RHEL virtual machine (VM), you can apply SEV-SNP configuration when creating the VM.

Alternatively, you can enable SEV-SNP in an existing RHEL VM by editing the VM configuration.

SEV-SNP is a hardware-based security feature that provides strong memory encryption and integrity protection for VMs. This isolates VMs from the hypervisor and other host system software. SEV-SNP is available only with AMD CPUs.

Prerequisites

- SEV-SNP is enabled on your RHEL host. For instructions, see A RHEL host with SEV-SNP enabled
- The host has **libvirt**, **virt-install**, and **virt-xml** installed
- The VM uses a supported RHEL version as the guest operating system:
  - RHEL 9.2 or later
  - RHEL 10.0 or later

Procedure

- To create a new RHEL VM with SEV-SNP enabled:
  - Use the **virt-install** utility with the **--launchSecurity sev-snp,policy=0x30000** option. For example:

    ```
    # virt-install \
        --name <vm_name> --os-info rhel9.6 --memory 2048 --vcpus 2 \
        --boot uefi --import --disk /var/lib/libvirt/images/disk.qcow2 \
        --graphics none --console pty,target_type=serial \
        --launchSecurity sev-snp,policy=0x30000
    ```

- To enable SEV-SNP functionality in an existing RHEL VM:

  a. Shut down the existing virtual machine if it is running.

    ```
    # virsh shutdown <vm_name>
    ```

  b. Export and back up the current VM configuration.

    ```
    # virsh dumpxml <vm_name> > /tmp/<vm_name>-backup.xml
    ```

  c. Add SEV-SNP launch security configuration to the VM domain.

    ```
    # virt-xml <vm_name> --edit --launchSecurity type=sev-snp,policy=0x30000
    ```

    This command adds the SEV-SNP configuration to the VM's domain XML. Alternatively, you can manually edit the configuration by using **virsh edit *vm-name*** and add the **<launchSecurity type='sev-snp'>** element.

  d. Ensure the VM is configured with a compatible CPU model.

    ```
    # virsh dumpxml <vm_name> --xpath //cpu

    <cpu mode="host-passthrough" check="none" migratable="on"/>
    ```

    The CPU should be set to **host-passthrough** or use an AMD EPYC model. If not, update it:

    ```
    # virt-xml <vm_name> --edit --cpu mode=host-passthrough
    ```

  e. Start the VM.

```
# virsh start <vm_name>
```

Verification

1. On the host, verify that the VM is running with SEV-SNP enabled.

   ```
   # virsh dumpxml --xpath //launchSecurity <vm_name>

   <launchSecurity type="sev-snp">
     <policy>0x00030000</policy>
   </launchSecurity>
   ```

2. Log in to the guest VM.

3. Verify that the SEV-SNP guest device exists.

   ```
   # ls -l /dev/sev_guest
   ```

   If SEV-SNP is properly enabled in the guest, this command lists the **/dev/sev_guest** character device.

> **IMPORTANT**
>
> Checking the existence of **/dev/sev_guest** proves only that the VM is configured and operating correctly. To prove that the VM is using SEV-SNP to secure it against a hostile host, you must perform a cryptographic attestation of the guest.
>
> For more information about attestation, see Learn about Confidential Computing Attestation (Red Hat Blog)

Troubleshooting

- If SEV-SNP is not detected in the guest, verify that the host SEV-SNP configuration is correct and that the VM was restarted after the configuration change.

- To revert to the original configuration, restore from the backup:

  ```
  # virsh undefine <vm_name>
  # virsh define /tmp/<vm_name>-backup.xml
  ```

Additional resources

- Learn about Confidential Computing Attestation (Red Hat Blog)

19.13. ENABLING TDX

Trust Domain Extensions (TDX) is a hardware-based security feature that provides strong memory encryption and integrity protection for virtual machines (VMs), that isolates VMs from the hypervisor and other host system software. TDX is available only with Intel CPUs.

IMPORTANT

Enabling TDX on a RHEL host is a Technology Preview only. However, enabling TDX on a RHEL guest is fully supported.

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

19.13.1. Enabling TDX on a RHEL host

To enable Trust Domain Extensions (TDX) on a RHEL host, you must ensure that your system meets the prerequisites, then install the **libvirt-daemon-kvm** and **tdx-qgs** packages.

TDX is a hardware-based security feature that provides strong memory encryption and integrity protection for virtual machines (VMs), that isolates VMs from the hypervisor and other host system software. TDX is available only with Intel CPUs.

IMPORTANT

Using TDX on a RHEL host is a Technology Preview only. Technology Preview features are not supported with Red Hat production service levels 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

- Intel CPU that supports TDX, such as 4th Generation Intel Xeon Scalable Processors or newer
- Your host uses the following hardware and software:
  - RHEL 9.7 or later
  - TDX firmware version 1.5 or later
- The following settings are enabled in the UEFI CPU menu:
  - **Software Guard Extensions (SGX)**
  - **Total Memory Encryption (TME)**
  - **Total Memory Encryption Multi-Tenant (TME-MT)**
  - **Trust Domain Extension (TDX)**
  - **TDX Secure Arbitration Mode Loader (SEAM Loader)**

Procedure

1. Install the necessary packages on the RHEL host.

```
# dnf install libvirt-daemon-kvm tdx-qgs
```

2. Disable hibernation on the host and enable IOMMU.

   ```
   # grubby --update-kernel=ALL --args="nohibernate intel_iommu=on"
   ```

   Hibernation must be disabled for TDX to function properly.

3. Update the bootloader configuration and reboot the system.

   ```
   # grub2-mkconfig -o /boot/grub2/grub.cfg
   # reboot
   ```

   The system must be rebooted for the TDX configuration to take effect.

Verification

- Verify that TDX is enabled on the host.

  ```
  # virt-host-validate qemu

    QEMU: Checking for hardware virtualization:   PASS
    QEMU: Checking if device '/dev/kvm' exists:   PASS
    QEMU: Checking if device '/dev/kvm' is accessible:   PASS
    QEMU: Checking if device '/dev/vhost-net' exists:   PASS
    QEMU: Checking if device '/dev/net/tun' exists:   PASS
    QEMU: Checking for cgroup 'cpu' controller support:   PASS
    QEMU: Checking for cgroup 'cpuacct' controller support:   PASS
    QEMU: Checking for cgroup 'cpuset' controller support:   PASS
    QEMU: Checking for cgroup 'memory' controller support:   PASS
    QEMU: Checking for cgroup 'devices' controller support:   PASS
    QEMU: Checking for cgroup 'blkio' controller support:   PASS
    QEMU: Checking for device assignment IOMMU support:   PASS
    QEMU: Checking if IOMMU is enabled by kernel:   PASS
    QEMU: Checking for secure guest support:   PASS
  ```

  If TDX is enabled on the host, the **Checking for secure guest support** line reports **PASS**.

Next steps

- Enabling TDX on a RHEL guest

19.13.2. Enabling TDX on a RHEL guest

To enable Domain Extensions (TDX) functionality in a RHEL virtual machine (VM), you can apply TDX configuration when creating the VM.

Alternatively, you can enable TDX in an existing RHEL VM by editing the VM configuration.

TDX is a hardware-based security feature that provides strong memory encryption and integrity protection for VMs, that isolates VMs from the hypervisor and other host system software. TDX is available only with Intel CPUs.

Prerequisites

- TDX is enabled on your RHEL host. For instructions, see A RHEL host with TDX enabled

- The host has **libvirt**, **virt-install**, and **virt-xml** installed.
- The VM uses a supported RHEL version as the guest operating system:
    - RHEL 9.6 or later
    - RHEL 10.0 or later

NOTE

TDX is incompatible with **kdump**. Enabling TDX in a VM will cause **kdump** to fail in that VM.

Procedure

- To create a new RHEL VM with TDX enabled:
    - Use the **virt-install** utility with the **--launchSecurity tdx,quoteGenerationService=on** option. For example:

      ```
      # virt-install \
          --name <vm_name> --os-info rhel9.6 --memory 2048 --vcpus 2 \
          --boot uefi --import --disk /var/lib/libvirt/images/disk.qcow2 \
          --graphics none --console pty,target_type=serial \
          --launchSecurity tdx,quoteGenerationService=on
      ```

- To enable TDX functionality in an existing RHEL VM:

    a. Shut down the existing VM if it is running.

    ```
    # virsh shutdown <vm_name>
    ```

    b. Export and back up the current VM configuration.

    ```
    # virsh dumpxml <vm_name> > /tmp/<vm_name>-backup.xml
    ```

    c. Add TDX launch security configuration to the VM domain.

    ```
    # virt-xml <vm_name> --edit --launchSecurity type=tdx
    ```

    This command adds the TDX configuration to the VM’s domain XML. Alternatively, you can manually edit the configuration by using **virsh edit *<vm_name>*** and add the **<launchSecurity type='tdx'>** element.

    d. Ensure the VM is configured with a compatible CPU model.

    ```
    # virsh dumpxml <vm_name> --xpath //cpu

    <cpu mode="host-passthrough" check="none" migratable="on"/>
    ```

    The CPU should be set to **host-passthrough** or use an Intel Xeon model. If not, update it:

    ```
    # virt-xml <vm_name> --edit --cpu mode=host-passthrough
    ```

e. Start the VM.

```
# virsh start <vm_name>
```

Verification

1. On the host, verify that the VM is running with TDX enabled.

```
# virsh dumpxml --xpath //launchSecurity <vm_name>

<launchSecurity type="tdx">
  <quoteGenerationService/>
</launchSecurity>
```

2. Log in to the VM.

3. Verify that the TDX guest device exists.

```
# ls -l /dev/tdx_guest
```

If TDX is properly enabled in the guest, this command lists the **/dev/tdx_guest** character device.

IMPORTANT

Checking the existence of **/dev/tdx_guest** proves only that the VM is configured and operating correctly. To prove that the VM is using TDX to secure it against a hostile host, you must perform a cryptographic attestation of the guest.

For more information about attestation, see Learn about Confidential Computing Attestation (Red Hat Blog)

Troubleshooting

- If TDX is not detected in the guest, verify that the host TDX configuration is correct and that the VM was restarted after the configuration change.
- To revert to the original configuration, restore from the backup:

```
# virsh undefine <vm_name>
# virsh define /tmp/<vm_name>-backup.xml
```

Additional resources

- Learn about Confidential Computing Attestation (Red Hat Blog)

CHAPTER 20. SHARING FILES BETWEEN THE HOST AND ITS VIRTUAL MACHINES

You may frequently require to share data between your host system and the virtual machines (VMs) it runs. To do so quickly and efficiently, you can set up NFS file shares on your system. Alternatively, you can also use the **virtiofs** to share data with your Linux and Windows VMs.

20.1. SHARING FILES BETWEEN THE HOST AND ITS VIRTUAL MACHINES BY USING NFS

For efficient file sharing between the RHEL 9 host system and the virtual machines (VMs), you can export an NFS share that VMs can mount and access.

However with Linux VMs, it is usually more convenient to use the **virtiofs** feature.

Prerequisites

- The **nfs-utils** package is installed on the host.

  ```
  # dnf install nfs-utils -y
  ```

- Virtual network of **NAT** or **bridge** type is configured to connect a host to VMs.

- Optional: For improved security, ensure your VMs are compatible with NFS version 4 or later.

Procedure

1. On the host, export a directory with the files you want to share as a network file system (NFS):

   a. Share an existing directory with VMs. If you do not want to share any of the existing directories, create a new one:

   ```
   # mkdir shared-files
   ```

   b. Obtain the IP address of each VM to share files from the host, for example, *testguest1* and *testguest2* :

   ```
   # virsh domifaddr testguest1
   Name       MAC address          Protocol     Address
   ----------------------------------------------------------------
   vnet0      52:53:00:84:57:90    ipv4         192.0.2.2/24

   # virsh domifaddr testguest2
   Name       MAC address          Protocol     Address
   ----------------------------------------------------------------
   vnet1      52:53:00:65:29:21    ipv4         192.0.2.3/24
   ```

   c. Edit the **/etc/exports** file on the host and add a line that includes the directory you want to share, IPs of VMs to share, and additional options:

   ```
   /home/<username>/Downloads/<shared_directory>/ <VM1-IP(options)> <VM2-
   IP(options)>
   ...
   ```

The following example shares the **/usr/local/shared-files** directory on the host with *testguest1* and *testguest2*, and enables the VMs to edit the content of the directory:

```
/usr/local/shared-files/ 192.0.2.2(rw,sync) 192.0.2.3(rw,sync)
```

NOTE

To share a directory with a Windows VM, you need to ensure the Windows NFS client has write permissions in the shared directory. You can use the **all_squash**, **anonuid**, and **anongid** options in the **/etc/exports** file.

/usr/local/shared-files/ 192.0.2.2(rw,sync,all_squash,anonuid=*<directory-owner-UID>*,anongid=*<directory-owner-GID>*)

The *<directory-owner-UID>* and *<directory-owner-GID>* are the UID and GID of the local user that owns the shared directory on the host.

For other options to manage NFS client permissions, follow the Securing the NFS service guide.

d. Export the updated file system:

```
# exportfs -a
```

e. Start the **nfs-server** service:

```
# systemctl start nfs-server
```

f. Obtain the IP address of the host system to mount the shared directory on the VMs:

```
# ip addr
...
5: virbr0: [BROADCAST,MULTICAST,UP,LOWER_UP] mtu 1500 qdisc noqueue state
UP group default qlen 1000
link/ether 52:54:00:32:ff:a5 brd ff:ff:ff:ff:ff:ff
inet 192.0.2.1/24 brd 192.0.2.255 scope global virbr0
valid_lft forever preferred_lft forever
...
```

Note that the relevant network connects the host with VMs to share files. Usually, this is **virbr0**.

2. Mount the shared directory on a Linux VM that is specified in the **/etc/exports** file:

```
# mount 192.0.2.1:/usr/local/shared-files /mnt/host-share
```

- **192.0.2.1**: The IP address of the host.
- **/usr/local/shared-files**: A file-system path to the exported directory on the host.
- **/mnt/host-share**: A mount point on the VM

NOTE

The mount point must be an empty directory.

3. To mount the shared directory on a Windows VM as mentioned in the **/etc/exports** file:

    a. Open a PowerShell shell prompt as an Administrator.

    b. Install the **NFS-Client** package on the Windows.

        i. To install on a server version, enter:

        ```
        # Install-WindowsFeature NFS-Client
        ```

        ii. To install on a desktop version, enter:

        ```
        # Enable-WindowsOptionalFeature -FeatureName ServicesForNFS-ClientOnly,
        ClientForNFS-Infrastructure -Online -NoRestart
        ```

    c. Mount the directory exported by the host on a Windows VM:

    ```
    # C:\Windows\system32\mount.exe -o anon \\192.0.2.1\usr\local\shared-files Z:
    ```

    In this example:

    - **192.0.2.1**: The IP address of the host.
    - **/usr/local/shared-files**: A file system path to the exported directory on the host.
    - **Z:**: The drive letter for a mount point.

    NOTE

    You must choose a drive letter that is not in use on the system.

Verification

- List the contents of the shared directory on the VM so that you can share files between the host and the VM:

  ```
  $ ls <mount_point>
  shared-file1  shared-file2  shared-file3
  ```

  In this example, replace *<mount_point>* with a file system path to the mounted shared directory.

Additional resources

- Deploying an NFS server

20.2. SHARING FILES BETWEEN THE HOST AND ITS VIRTUAL MACHINES BY USING VIRTIOFS

Using virtiofs, you can share files between your host and your virtual machines (VM) as a directory tree that works the same as the local file system structure.

20.2.1. Sharing files between the host and its virtual machines by using virtiofs

When using RHEL 9 as your hypervisor, you can efficiently share files between your host system and its virtual machines (VM) using the **virtiofs** feature.

Prerequisites

- Virtualization is installed and enabled on your RHEL 9 host.
- A directory that you want to share with your VMs. If you do not want to share any of your existing directories, create a new one, for example named *shared-files*.

  ```
  # mkdir /root/shared-files
  ```

- The VM you want to share data with is using a Linux distribution as its guest operating system.

Procedure

1. For each directory on the host that you want to share with your VM, set it as a virtiofs file system in the VM's XML configuration.

   a. Open the XML configuration of the intended VM.

      ```
      # virsh edit vm-name
      ```

   b. Add an entry similar to the following to the **<devices>** section of the VM's XML configuration.

      ```
      <filesystem type='mount' accessmode='passthrough'>
        <driver type='virtiofs'/>
        <binary path='/usr/libexec/virtiofsd' xattr='on'/>
        <source dir='/root/shared-files'/>
        <target dir='host-file-share'/>
      </filesystem>
      ```

      This example sets the **/root/shared-files** directory on the host to be visible as **host-file-share** to the VM.

2. Set up shared memory for the VM. To do so, add shared memory backing to the **<domain>** section of the XML configuration:

   ```
   <domain>
    [...]
    <memoryBacking>
      <access mode='shared'/>
    </memoryBacking>
    [...]
   </domain>
   ```

3. Boot up the VM.

```
# virsh start vm-name
```

4. Mount the file system in the guest operating system. The following example mounts the previously configured **host-file-share** directory with a Linux guest operating system.

```
# mount -t virtiofs host-file-share /mnt
```

Verification

- Ensure that the shared directory became accessible on the VM and that you can now open files stored in the directory.

Known issues and limitations

- File-system mount options related to access time, such as **noatime** and **strictatime**, are not likely to work with virtiofs, and Red Hat discourages their use.

Troubleshooting

- If **virtiofs** is not optimal for your usecase or supported for your system, you can use NFS instead.

20.2.2. Sharing files between the host and Windows virtual machines by using virtiofs

When using RHEL 9 as your hypervisor, you can efficiently share files between your host system and Windows virtual machines (VM) using the **virtiofs** feature along with the **virtio-win** package.

NOTE

You can run the **virtiofs** service in case insensitive mode on a Windows VM using the **virtiofs.exe** command and the **-i** parameter.

Prerequisites

- You have configured your VM's XML configuration file to use virtiofs. For detailed information, see Section 20.2.1, "Sharing files between the host and its virtual machines by using virtiofs" .
- You have attached the **virtio** driver installation media to the VM .
- You have installed the **virtio-win** package on your Windows VM. For more information, see Installing virtio drivers on a Windows guest .

Procedure

1. On your Windows VM, install WinFsp. To do so, mount the **virtio-win** ISO image, start the **winfsp** MSI installer, and follow the prompts.
   In the **Custom Setup** window of the installation wizard, select the features you want to install on the VM.

2. Start the virtiofs service:

```
# sc start VirtioFsSvc
```

3. Navigate to **This PC**:
   File Explorer → This PC

   Virtiofs should be available on the Windows VM as the first available drive letter starting with **z:** and going backwards. For example, **my_viofs (Z:)**.

   IMPORTANT

   You must restart the virtiofs service after each VM reboot to access the shared directory.

4. Optional: To set up additional virtiofs instances:

   a. Stop the virtiofs service:

   ```
   # sc stop VirtioFsSvc
   # sc config VirtioFsSvc start=demand
   ```

   b. Configure the WinFSP.Launcher service to set up multiple virtiofs instances:

   ```
   # "C:\Program Files (x86)\WinFsp\bin\fsreg.bat" virtiofs "<path to the binary>\virtiofs.exe"
   "-t %1 -m %2"
   ```

   c. Mount virtiofs instances to drives.
   For example, to mount virtiofs with the tag **mount_tag0** to the **Y:** drive:

   ```
   "C:\Program Files (x86)\WinFsp\bin\launchctl-x64.exe" start virtiofs viofsY mount_tag0 Y:
   ```

   d. Repeat the previous step to mount all of your virtiofs instances.

   e. To unmount the virtiofs instance:

   ```
   "C:\Program Files (x86)\WinFsp\bin\launchctl-x64.exe" stop virtiofs viofsY
   ```

Verification

1. On your Windows VM, navigate to **This PC**:
   File Explorer → This PC

   - If you did not specify a mount point when setting up the virtiofs service, it will use the first available drive letter starting with **z:** and going backwards.

   - If you have multiple virtiofs instances set up, they will appear as drives with the letters you had assigned to the instances.

20.2.3. Sharing files between the host and its virtual machines by using virtiofs in the web console

You can use the RHEL web console to efficiently share files between your host system and its virtual machines (VM) using the **virtiofs** feature.

Prerequisites

Prerequisites

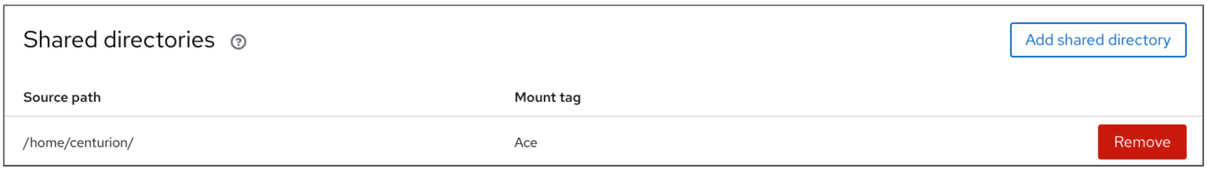
- The web console VM plug-in is installed on your system .
- A directory that you want to share with your VMs. If you do not want to share any of your existing directories, create a new one, for example named *centurion*.

```
# mkdir /home/centurion
```

- The VM you want to share data with is using a Linux distribution as its guest operating system.

Procedure

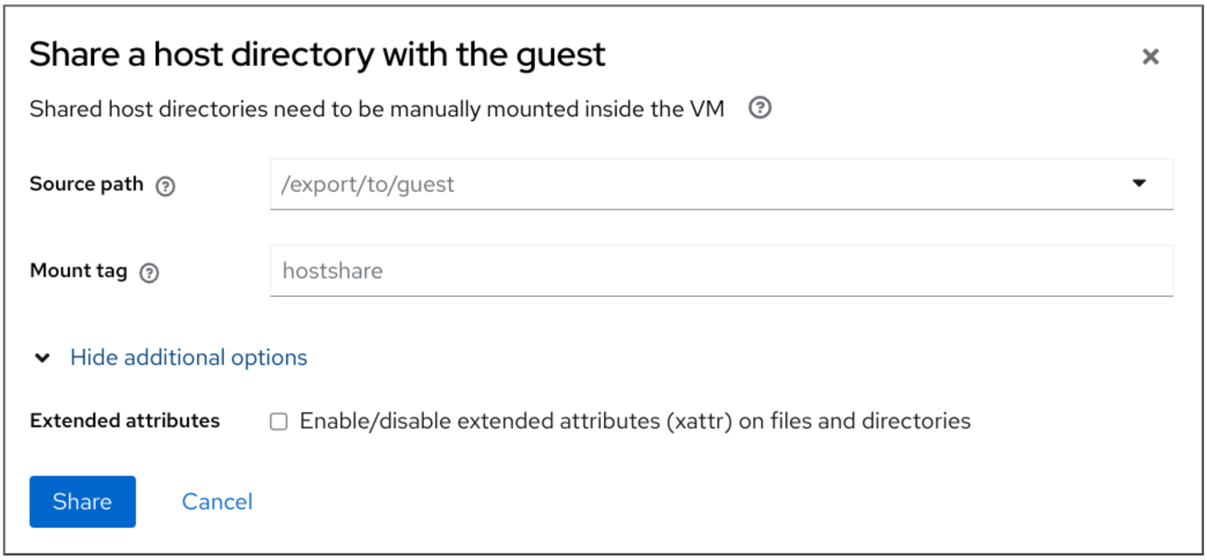
1. In the **Virtual Machines** interface, click the VM with which you want to share files.
   A new page opens with an **Overview** section with basic information about the selected VM and a **Console** section.
2. Scroll to **Shared directories**.
   The **Shared directories** section displays information about the host files and directories shared with that VM and options to **Add** or **Remove** a shared directory.



Shared directories ⓘ

Source path	Mount tag
/home/centurion/	Ace

3. Click **Add shared directory**.
   The **Share a host directory with the guest**dialog appears.



Share a host directory with the guest

Shared host directories need to be manually mounted inside the VM ⓘ

Source path ⓘ /export/to/guest

Mount tag ⓘ hostshare

Extended attributes ☐ Enable/disable extended attributes (xattr) on files and directories

4. Enter the following information:
   - **Source path** - The path to the host directory that you want to share.
   - **Mount tag** - The tag that the VM uses to mount the directory.
5. Set additional options:
   - **Extended attributes** - Set whether to enable extended attributes, **xattr**, on the shared files and directories.

6. Click **Share**.
   The selected directory is shared with the VM.

Verification

- Ensure that the shared directory is accessible on the VM and you can now open files stored in that directory.

20.2.4. Using the web console to remove shared files between the host and its virtual machines by using virtiofs

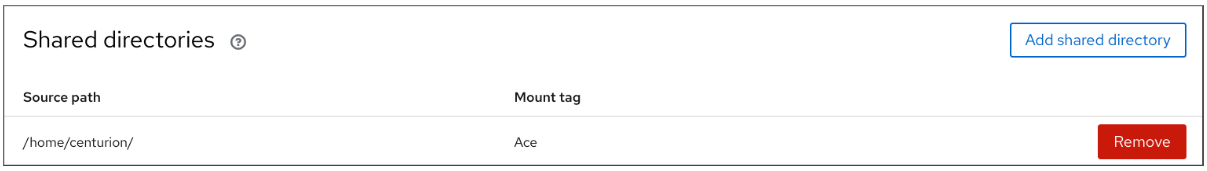
You can use the RHEL web console to remove files shared between your host system and its virtual machines (VM) using the **virtiofs** feature.

Prerequisites

- The web console VM plug-in is installed on your system.
- The directory is no longer being used by the VM.

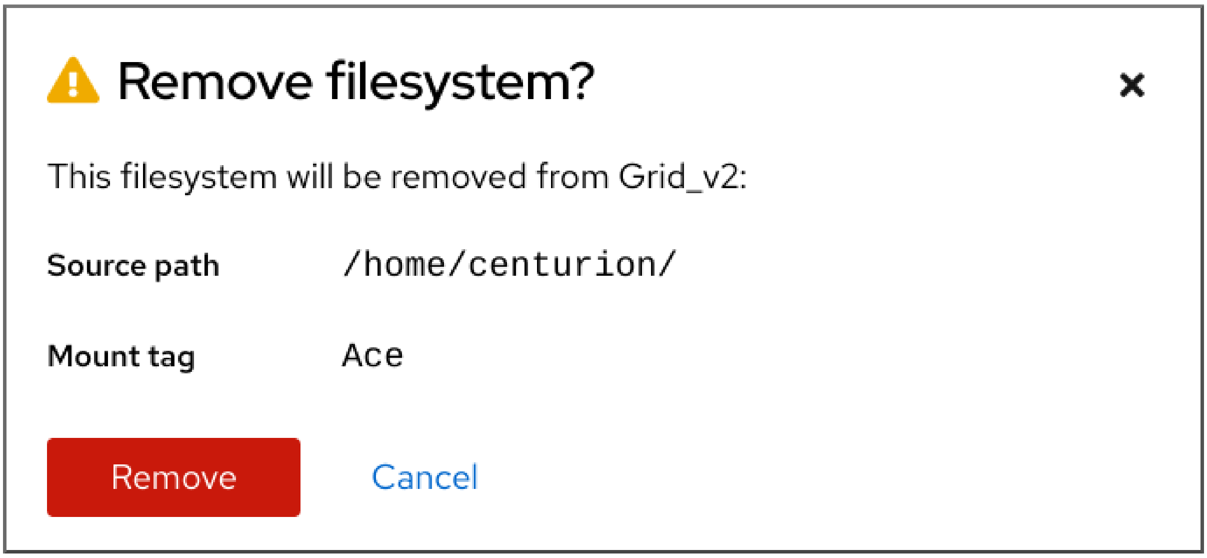
Procedure

1. In the **Virtual Machines** interface, click on the VM from which you want to remove the shared files.
   A new page opens with an **Overview** section with basic information about the selected VM and a **Console** section.
2. Scroll to **Shared directories**.
   The **Shared directories** section displays information about the host files and directories shared with that VM and options to **Add** or **Remove** a shared directory.



Source path	Mount tag
/home/centurion/	Ace

3. Click **Remove** next to the directory that you want to unshare with the VM.
   The **Remove filesystem** dialog appears.



Remove filesystem?

This filesystem will be removed from Grid_v2:

Source path	/home/centurion/
Mount tag	Ace

4. Click **Remove**.
   The selected directory is unshared with the VM.

Verification

- The shared directory is no longer available and accessible on the VM.

CHAPTER 21. INSTALLING AND MANAGING WINDOWS VIRTUAL MACHINES

To use Microsoft Windows as the guest operating system in your virtual machines (VMs) on a RHEL 9 host, Red Hat recommends taking extra steps to ensure these VMs run correctly.

For this purpose, the following sections provide information about installing and optimizing Windows VMs on the host, as well as installing and configuring drivers in these VMs.

21.1. INSTALLING WINDOWS VIRTUAL MACHINES

You can create a fully-virtualized Windows machine on a RHEL 9 host, launch the graphical Windows installer inside the virtual machine (VM), and optimize the installed Windows guest operating system (OS).

To create the VM and to install the Windows guest OS, use the **virt-install** command or the RHEL 9 web console.

Prerequisites

- A Windows OS installation source, which can be one of the following, and be available locally or on a network:
  - An ISO image of an installation medium
  - A disk image of an existing VM installation
- A storage medium with the KVM **virtio** drivers.
  To create this medium, see Preparing virtio driver installation media on a host machine .
- If you are installing Windows 11, the **edk2-ovmf**, **swtpm** and **libtpms** packages must be installed on the host.

Procedure

1. Create the VM. For instructions, see Creating virtual machines, but keep in mind the following specifics.
   - If using the **virt-install** utility to create the VM, add the following options to the command:
     - The storage medium with the KVM **virtio** drivers. For example:

       ```
       --disk path=/usr/share/virtio-win/virtio-win.iso,device=cdrom
       ```

     - The Windows version you will install. For example, for Windows 10 and 11:

       ```
       --os-variant win10
       ```

       For a list of available Windows versions and the appropriate option, use the following command:

       ```
       # osinfo-query os
       ```

    - If you are installing Windows 11, enable *Unified Extensible Firmware Interface* (UEFI) and *virtual Trusted Platform Module* (vTPM):

      ```
      --boot uefi
      ```

  - If using the web console to create the VM, specify your version of Windows in the **Operating system** field of the **Create new virtual machine** window.

    - If you are installing Windows versions prior to Windows 11 and Windows Server 2022, start the installation by clicking **Create and run**.

    - If you are installing Windows 11, or you want to use additional Windows Server 2022 features, confirm by clicking **Create and edit** and enable UEFI and vTPM using the CLI:

      A. Open the VM's XML configuration:

      ```
      # virsh edit windows-vm
      ```

      B. Add the **firmware='efi'** option to the **os** element:

      ```
      <os firmware='efi'>
        <type arch='x86_64' machine='pc-q35-6.2'>hvm</type>
        <boot dev='hd'/>
      </os>
      ```

      C. Add the **tpm** device inside the **devices** element:

      ```
      <devices>
        <tpm model='tpm-crb'>
          <backend type='emulator' version='2.0'/>
        </tpm>
      </devices>
      ```

      D. Start the Windows installation by clicking **Install** in the **Virtual machines** table.

2. Install the Windows OS in the VM.
   For information about how to install a Windows operating system, refer to the relevant Microsoft installation documentation.

3. If using the web console to create the VM, attach the storage medium with virtio drivers to the VM by using the **Disks** interface. For instructions, see Attaching existing disks to virtual machines by using the web console.

4. Configure KVM **virtio** drivers in the Windows guest OS. For details, see Installing KVM paravirtualized drivers for Windows virtual machines.

Additional resources

- Optimizing Windows virtual machines
- Enabling standard hardware security on Windows virtual machines
- Enabling enhanced hardware security on Windows virtual machines
- Sample virtual machine XML configuration

21.2. OPTIMIZING WINDOWS VIRTUAL MACHINES

When using Microsoft Windows as a guest operating system in a virtual machine (VM) hosted in RHEL 9, the performance of the guest may be negatively impacted.

Therefore, Red Hat recommends optimizing your Windows VMs by doing any combination of the following:

- Using paravirtualized drivers. For more information, see Installing KVM paravirtualized drivers for Windows virtual machines.
- Enabling Hyper-V enlightenments. For more information, see Enabling Hyper-V enlightenments.
- Configuring NetKVM driver parameters. For more information, see Configuring NetKVM driver parameters.
- Optimizing or disabling Windows background processes. For more information, see Optimizing background processes on Windows virtual machines.

21.2.1. Installing KVM paravirtualized drivers for Windows virtual machines

The primary method of improving the performance of your Windows virtual machines (VMs) is to install KVM paravirtualized (**virtio**) drivers for Windows on the guest operating system.

NOTE

The **virtio-win** drivers are certified (WHQL) against the latest releases of Windows 10 and 11, available at the time of the respective **virtio-win** release. However, **virtio-win** drivers are generally tested and expected to function correctly on previous builds of Windows 10 and 11 as well.

To install the drivers on a Windows VM, perform the following actions:

1. Prepare the install media on the host machine. For more information, see Preparing virtio driver installation media on a host machine.
2. Attach the install media to an existing Windows VM, or attach it when creating a new Windows VM. For more information, see Installing Windows virtual machines on RHEL .
3. Install the **virtio** drivers on the Windows guest operating system. For more information, see Installing virtio drivers on a Windows guest .
4. Install the **QEMU Guest Agent** on the Windows guest operating system. For more information, see Installing QEMU Guest Agent on a Windows guest .

21.2.1.1. How Windows virtio drivers work

Paravirtualized drivers enhance the performance of virtual machines (VMs) by decreasing I/O latency and increasing throughput to almost bare-metal levels. Red Hat recommends that you use paravirtualized drivers for VMs that run I/O-heavy tasks and applications.

virtio drivers are KVM's paravirtualized device drivers, available for Windows VMs running on KVM hosts. These drivers are provided by the **virtio-win** package, which includes drivers for:

- Block (storage) devices

- Network interface controllers
- Video controllers
- Memory ballooning device
- Paravirtual serial port device
- Entropy source device
- Paravirtual panic device
- Input devices, such as mice, keyboards, or tablets
- A small set of emulated devices

NOTE

For additional information about emulated, **virtio**, and assigned devices, refer to Managing virtual devices.

By using KVM virtio drivers, the following Microsoft Windows versions are expected to run similarly to physical systems:

- Windows Server versions: See Certified guest operating systems for Red Hat Enterprise Linux with KVM in the Red Hat Knowledgebase.
- Windows Desktop (non-server) versions:
  - Windows 10 (32-bit and 64-bit versions)
  - Windows 11 (64-bit)

21.2.1.2. Preparing virtio driver installation media on a host machine

To install or update KVM **virtio** drivers on a Windows virtual machine (VM), you must first prepare the **virtio** driver installation media on the host machine. To do so, attach the **.iso** file, provided by the **virtio-win** package, as a storage device to the Windows VM.

Prerequisites

- Ensure that virtualization is enabled in your RHEL 9 host system. For more information, see Enabling virtualization.
- Ensure that you have root access privileges to the VM.

Procedure

1. Refresh your subscription data:

```
# subscription-manager refresh
All local data refreshed
```

2. Get the latest version of the **virtio-win** package.

- If **virtio-win** is not installed:

  ```
  # dnf install -y virtio-win
  ```

- If **virtio-win** is installed:

  ```
  # dnf upgrade -y virtio-win
  ```

  If the installation succeeds, the **virtio-win** driver files are available in the **/usr/share/virtio-win/** directory. These include **ISO** files and a **drivers** directory with the driver files in directories, one for each architecture and supported Windows version.

  ```
  # ls /usr/share/virtio-win/
  drivers/  guest-agent/  virtio-win-1.9.9.iso  virtio-win.iso
  ```

3. Attach the **virtio-win.iso** file as a storage device to the Windows VM.

   - When creating a new Windows VM , attach the file by using the **virt-install** command options.

   - When installing the drivers on an existing Windows VM, attach the file as a CD-ROM by using the **virt-xml** utility:

     ```
     # virt-xml WindowsVM --add-device --disk virtio-win.iso,device=cdrom
     Domain 'WindowsVM' defined successfully.
     ```

Additional resources

- Installing the virtio driver on the Windows guest operating system .

21.2.1.3. Installing virtio drivers on a Windows guest

To install KVM **virtio** drivers on a Windows guest operating system, you must add a storage device that contains the drivers (either when creating the virtual machine (VM) or afterwards) and install the drivers in the Windows guest operating system.

This procedure provides instructions to install the drivers by using the graphical interface. You can also use the Microsoft Windows Installer (MSI) command-line interface.

Prerequisites

- An installation medium with the KVM **virtio** drivers must be attached to the VM. For instructions on preparing the medium, see Preparing virtio driver installation media on a host machine .

Procedure

1. In the Windows guest operating system, open the **File Explorer** application.

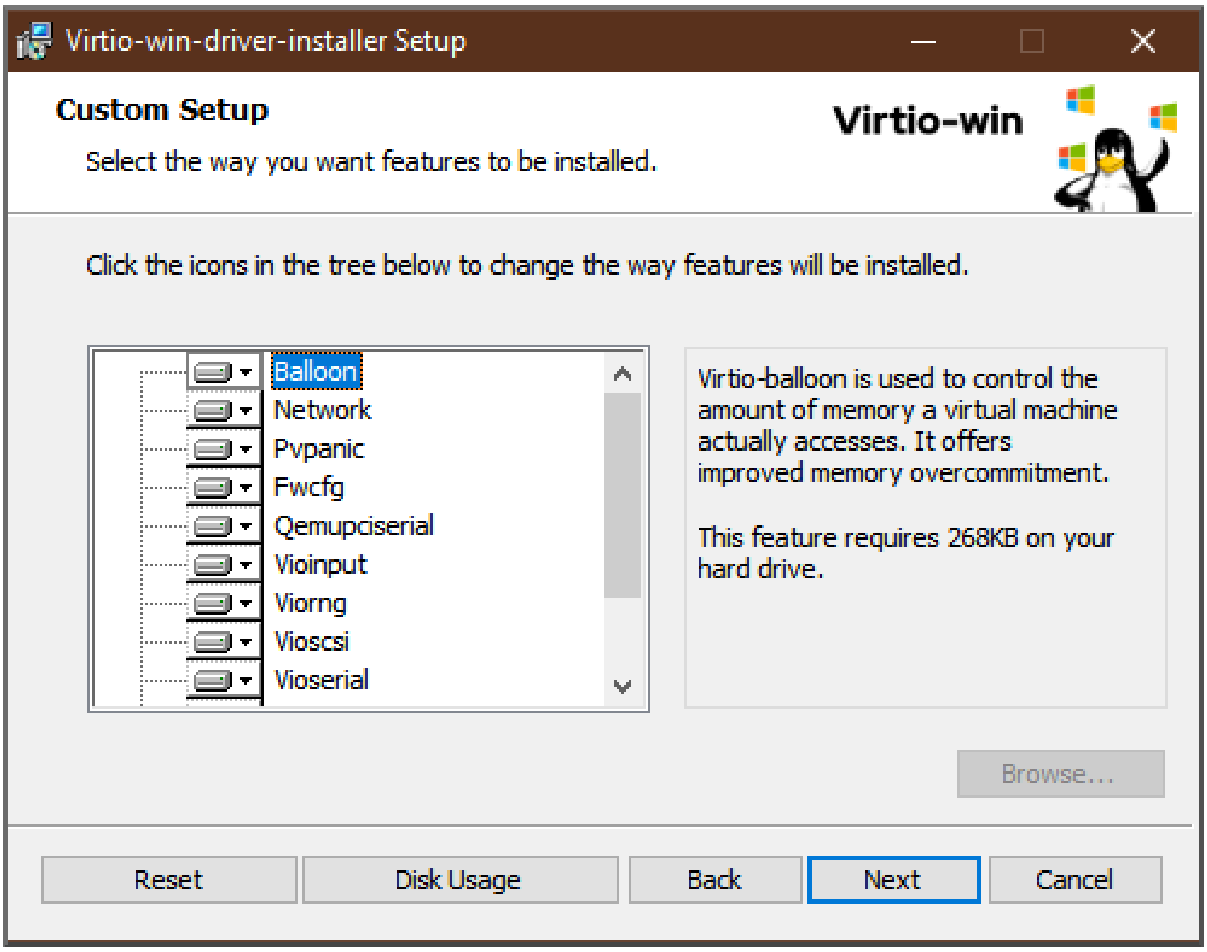
2. Click **This PC**.

3. In the **Devices and drives** pane, open the **virtio-win** medium.

4. Based on the operating system installed on the VM, run one of the installers:

- If using a 32-bit operating system, run the **virtio-win-gt-x86.msi** installer.
- If using a 64-bit operating system, run the **virtio-win-gt-x64.msi** installer.

5. In the **Virtio-win-driver-installer** setup wizard that opens, follow the displayed instructions until you reach the **Custom Setup** step.



Virtio-win-driver-installer Setup

Custom Setup

Select the way you want features to be installed.

Click the icons in the tree below to change the way features will be installed.

Virtio-balloon is used to control the amount of memory a virtual machine actually accesses. It offers improved memory overcommitment.

This feature requires 268KB on your hard drive.

6. In the Custom Setup window, select the device drivers you want to install. The recommended driver set is selected automatically, and the descriptions of the drivers are displayed on the right of the list.
7. Click **next**, then click **Install**.
8. After the installation completes, click **Finish**.
9. Reboot the VM to complete the driver installation.

Verification

1. On your Windows VM, navigate to the **Device Manager**:
   a. Click Start
   b. Search for **Device Manager**
2. Ensure that the devices are using the correct drivers:
   a. Click a device to open the **Driver Properties** window.
   b. Navigate to the **Driver** tab.

c. Click **Driver Details**.

Next steps

- If you installed the NetKVM driver, you might also need to configure the Windows guest’s networking parameters. For more information, see Configuring NetKVM driver parameters.

21.2.1.4. Updating virtio drivers on a Windows guest

To update KVM **virtio** drivers on a Windows guest operating system (OS), you can use the **Windows Update** service, if the Windows OS version supports it. If it does not, reinstall the drivers from **virtio** driver installation media attached to the Windows virtual machine (VM).

Prerequisites

- A Windows guest OS with virtio drivers installed.
- If not using **Windows Update**, an installation medium with up-to-date KVM **virtio** drivers must be attached to the Windows VM. For instructions on preparing the medium, see Preparing virtio driver installation media on a host machine.

Procedure 1: Updating the drivers by using Windows Update

On Windows 10, Windows Server 2016 and later operating systems, check if the driver updates are available by using the **Windows Update** graphical interface:

1. Start the Windows VM and log in to its guest OS.
2. Navigate to the **Optional updates** page:
   Settings → Windows Update → Advanced options → Optional updates
3. Install all updates from **Red Hat, Inc.**

Procedure 2: Updating the drivers by reinstalling them

On operating systems prior to Windows 10 and Windows Server 2016, or if the OS does not have access to **Windows Update**, reinstall the drivers. This restores the Windows guest OS network configuration to default (DHCP). If you want to preserve a customized network configuration, you also need to create a backup and restore it by using the **netsh** utility:

1. Start the Windows VM and log in to its guest OS.
2. Open the Windows Command Prompt:
   a. Use the **Super**+**R** keyboard shortcut.
   b. In the window that appears, type **cmd** and press **Ctrl**+**Shift**+**Enter** to run as administrator.
3. Back up the OS network configuration by using the Windows Command Prompt:

```
C:\WINDOWS\system32\netsh dump > backup.txt
```

4. Reinstall KVM **virtio** drivers from the attached installation media. Do one of the following:
   - Reinstall the drivers by using the Windows Command Prompt, where *X* is the installation media drive letter. The following commands install all **virtio** drivers.

  - If using a 64-bit vCPU:
    C:\WINDOWS\system32\msiexec.exe /i *X*:\virtio-win-gt-x64.msi /passive /norestart

  - If using a 32-bit vCPU:

    ```
    C:\WINDOWS\system32\msiexec.exe /i X:\virtio-win-gt-x86.msi /passive /norestart
    ```

- Reinstall the drivers using the graphical interface without rebooting the VM.

5. Restore the OS network configuration using the Windows Command Prompt:

   ```
   C:\WINDOWS\system32\netsh -f backup.txt
   ```

6. Reboot the VM to complete the driver installation.

Additional resources

- Microsoft documentation on Windows Update

21.2.1.5. Enabling QEMU Guest Agent on Windows guests

To allow a RHEL host to perform a certain subset of operations on a Windows virtual machine (VM), you must enable the QEMU Guest Agent (GA). To do so, add a storage device that contains the QEMU Guest Agent installer to an existing VM or when creating a new VM, and install the drivers on the Windows guest operating system.

To install the Guest Agent (GA) by using the graphical interface, see the procedure below. To install the GA on the command line, use the Microsoft Windows Installer (MSI) .

Prerequisites

- An installation medium with the Guest Agent is attached to the VM. For instructions on preparing the medium, see Preparing virtio driver installation media on a host machine .

Procedure

1. In the Windows guest operating system, open the **File Explorer** application.

2. Click **This PC**.

3. In the **Devices and drives** pane, open the **virtio-win** medium.

4. Open the **guest-agent** folder.

5. Based on the operating system installed on the VM, run one of the following installers:

   - If using a 32-bit operating system, run the **qemu-ga-i386.msi** installer.

   - If using a 64-bit operating system, run the **qemu-ga-x86_64.msi** installer.

6. Optional: If you want to use the para-virtualized serial driver (**virtio-serial**) as the communication interface between the host and the Windows guest, verify that the **virtio-serial** driver is installed on the Windows guest. For more information about installing **virtio** drivers, see: Installing virtio drivers on a Windows guest .

Verification

1. On your Windows VM, navigate to the **Services** window.
   Computer Management > Services

2. Ensure that the status of the **QEMU Guest Agent** service is **Running**.

Additional resources

- Virtualization features that require QEMU Guest Agent

21.2.2. Enabling Hyper-V enlightenments

Hyper-V enlightenments provide a method for KVM to emulate the Microsoft Hyper-V hypervisor. This improves the performance of Windows virtual machines.

The following sections provide information about the supported Hyper-V enlightenments and how to enable them.

21.2.2.1. Enabling Hyper-V enlightenments on a Windows virtual machine

Hyper-V enlightenments provide better performance in a Windows virtual machine (VM) running in a RHEL 9 host. For instructions on how to enable them, see the following.

Procedure

1. Use the **virsh edit** command to open the XML configuration of the VM. For example:

```
# virsh edit windows-vm
```

2. Add the following **<hyperv>** sub-section to the **<features>** section of the XML:

```
<features>
  [...]
  <hyperv>
    <relaxed state='on'/>
    <vapic state='on'/>
    <spinlocks state='on' retries='8191'/>
    <vendor_id state='on' value='KVM Hv'/>
    <vpindex state='on'/>
    <runtime state='on' />
    <synic state='on'/>
    <stimer state='on'>
      <direct state='on'/>
    </stimer>
    <frequencies state='on'/>
    <reset state='on'/>
    <tlbflush state='on'/>
    <reenlightenment state='on'/>
    <ipi state='on'/>
    <evmcs state='on'/>
  </hyperv>
  [...]
</features>
```

If the XML already contains a **<hyperv>** sub-section, modify it as shown above.

3. Change the **clock** section of the configuration as follows:

```
<clock offset='localtime'>
  ...
  <timer name='hypervclock' present='yes'/>
</clock>
```

4. Save and exit the XML configuration.

5. If the VM is running, restart it.

Verification

- Use the **virsh dumpxml** command to display the XML configuration of the running VM. If it includes the following segments, the Hyper-V enlightenments are enabled on the VM.

```
<hyperv>
  <relaxed state='on'/>
  <vapic state='on'/>
  <spinlocks state='on' retries='8191'/>
  <vendor_id state='on' value='KVM Hv'/>
  <vpindex state='on'/>
  <runtime state='on' />
  <synic state='on'/>
  <frequencies state='on'/>
  <reset state='on'/>
  <tlbflush state='on'/>
  <reenlightenment state='on'/>
  <stimer state='on'>
    <direct state='on'/>
  </stimer>
  <ipi state='on'/>
  <evmcs state='on'/>
</hyperv>

<clock offset='localtime'>
  ...
  <timer name='hypervclock' present='yes'/>
</clock>
```

21.2.2.2. Configurable Hyper-V enlightenments

You can configure certain Hyper-V features to optimize Windows VMs. The following table provides information about these configurable Hyper-V features and their values.

Table 21.1. Configurable Hyper-V features

Enlightenment	Description	Values

Enlightenment	Description	Values
evmcs	Implements paravirtualized protocol between L0 (KVM) and L1 (Hyper-V) hypervisors, which enables faster L2 exits to the hypervisor. **NOTE** This feature is exclusive to Intel processors.	on, off
frequencies	Enables Hyper-V frequency Machine Specific Registers (MSRs).	on, off
ipi	Enables paravirtualized inter processor interrupts (IPI) support.	on, off
reenlightenment	Notifies when there is a time stamp counter (TSC) frequency change which only occurs during migration. It also allows the guest to keep using the old frequency until it is ready to switch to the new one.	on, off
relaxed	Disables a Windows sanity check that commonly results in a BSOD when the VM is running on a heavily loaded host. This is similar to the Linux kernel option no_timer_check, which is automatically enabled when Linux is running on KVM.	on, off
runtime	Sets processor time spent on running the guest code, and on behalf of the guest code.	on, off

Enlightenment	Description	Values
spinlocks	- Used by a VM's operating system to notify Hyper-V that the calling virtual processor is attempting to acquire a resource that is potentially held by another virtual processor within the same partition. - Used by Hyper-V to indicate to the virtual machine's operating system the number of times a spinlock acquisition should be attempted before indicating an excessive spin situation to Hyper-V.	on, off
stimer	Enables synthetic timers for virtual processors. Note that certain Windows versions revert to using HPET (or even RTC when HPET is unavailable) when this enlightenment is not provided, which can lead to significant CPU consumption, even when the virtual CPU is idle.	on, off
stimer-direct	Enables synthetic timers when an expiration event is delivered via a normal interrupt.	on, off.
synic	Together with stimer, activates the synthetic timer. Windows 8 uses this feature in periodic mode.	on, off
time	Enables the following Hyper-V-specific clock sources available to the VM, - MSR-based 82 Hyper-V clock source (HV_X64_MSR_TIME_REF_COUNT, 0x40000020) - Reference TSC 83 page which is enabled via MSR (HV_X64_MSR_REFERENCE_TSC, 0x40000021)	on, off

Enlightenment	Description	Values
tlbflush	Flushes the TLB of the virtual processors.	on, off
vapic	Enables virtual APIC, which provides accelerated MSR access to the high-usage, memory-mapped Advanced Programmable Interrupt Controller (APIC) registers.	on, off
vendor_id	Sets the Hyper-V vendor id.	● on, off ● Id value - string of up to 12 characters
vpindex	Enables virtual processor index.	on, off

21.2.3. Configuring NetKVM driver parameters

After the NetKVM driver is installed, you can configure it to better suit your environment. The parameters listed in the following procedure can be configured by using the Windows Device Manager (**devmgmt.msc**).

IMPORTANT

Modifying the driver's parameters causes Windows to reload that driver. This interrupts existing network activity.

Prerequisites

- The NetKVM driver is installed on the virtual machine.
  For more information, see Installing KVM paravirtualized drivers for Windows virtual machines .

Procedure

1. Open Windows Device Manager.
   For information about opening Device Manager, refer to the Windows documentation.

2. Locate the **Red Hat VirtIO Ethernet Adapter**.

   a. In the Device Manager window, click **+** next to Network adapters.

   b. Under the list of network adapters, double-click **Red Hat VirtIO Ethernet Adapter**.
   The **Properties** window for the device opens.

3. View the device parameters.
   In the **Properties** window, click the **Advanced** tab.

4. Modify the device parameters.

a. Click the parameter you want to modify.
   Options for that parameter are displayed.

b. Modify the options as needed.
   For information about the NetKVM parameter options, refer to NetKVM driver parameters.

c. Click **OK** to save the changes.

21.2.4. NetKVM driver parameters

The following table provides information about the configurable NetKVM driver logging parameters.

Table 21.2. Logging parameters

Parameter	Description 2
Logging.Enable	A Boolean value that determines whether logging is enabled. The default value is Enabled.
Logging.Level	An integer that defines the logging level. As the integer increases, so does the verbosity of the log. ● The default value is 0 (errors only). ● 1-2 adds configuration messages. ● 3-4 adds packet flow information. ● 5-6 adds interrupt and DPC level trace information. NOTE High logging levels will slow down your virtual machine.

The following table provides information about the configurable NetKVM driver initial parameters.

Table 21.3. Initial parameters

Parameter	Description
Assign MAC	A string that defines the locally-administered MAC address for the paravirtualized NIC. This is not set by default.
Init.Do802.1PQ	A Boolean value that enables Priority/VLAN tag population and removal support. The default value is Enabled.

Parameter	Description
Init.MaxTxBuffers	An integer that represents the number of TX ring descriptors that will be allocated. The value is limited by the size of Tx queue of QEMU. The default value is 1024. Valid values are: 16, 32, 64, 128, 256, 512, and 1024.
Init.MaxRxBuffers	An integer that represents the number of RX ring descriptors that will be allocated. The value is limited by the size of Tx queue of QEMU. The default value is 1024. Valid values are: 16, 32, 64, 128, 256, 512, 1024, 2048, and 4096.
Offload.Tx.Checksum	Specifies the TX checksum offloading capability. In Red Hat Enterprise Linux 9, the valid values for this parameter are: ● All (the default) which enables IP, TCP, and UDP checksum offloading for both IPv4 and IPv6 ● TCP/UDP(v4,v6) which enables TCP and UDP checksum offloading for both IPv4 and IPv6 ● TCP/UDP(v4) which enables TCP and UDP checksum offloading for IPv4 only ● TCP(v4) which enables only TCP checksum offloading for IPv4 only
Offload.Rx.Checksum	Specifies the RX checksum offloading capability. In Red Hat Enterprise Linux 9, the valid values for this parameter are: ● All (the default) which enables IP, TCP, and UDP checksum offloading for both IPv4 and IPv6 ● TCP/UDP(v4,v6) which enables TCP and UDP checksum offloading for both IPv4 and IPv6 ● TCP/UDP(v4) which enables TCP and UDP checksum offloading for IPv4 only ● TCP(v4) which enables only TCP checksum offloading for IPv4 only

Parameter	Description
Offload.Tx.LSO	Specifies the TX large segments offloading (LSO) capability. In Red Hat Enterprise Linux 9, the valid values for this parameter are: ● Maximal (the default) which enables LSO offloading for both TCPv4 and TCPv6 ● IPv4 which enables LSO offloading for TCPv4 only ● Disable which disables LSO offloading
MinRxBufferPercent	Specifies minimal amount of available buffers in RX queue in percent of total amount of RX buffers. If the actual number of available buffers is lower than that value, the NetKVM driver indicates low resources condition to the operating system (requesting it to return the RX buffers as soon as possible) Minimum value (default) - **0**, meaning the driver never indicates low resources condition. Maximum value - **100**, meaning the driver indicates low resources condition all the time.

Additional resources

- INF enumeration keywords
- INF keywords that can be edited

21.2.5. Optimizing background processes on Windows virtual machines

To optimize the performance of a virtual machine (VM) running a Windows OS, you can configure or disable a variety of Windows processes.

WARNING

Certain processes might not work as expected if you change their configuration.

Procedure

You can optimize your Windows VMs by performing any combination of the following:

- Remove unused devices, such as USBs or CD-ROMs, and disable the ports.

- Disable background services, such as SuperFetch and Windows Search. For more information about stopping services, see Disabling system services or Stop-Service.
- Disable **useplatformclock**. To do so, run the following command,

  ```
  # bcdedit /set useplatformclock No
  ```

- Review and disable unnecessary scheduled tasks, such as scheduled disk defragmentation. For more information about how to do so, see Disable Scheduled Tasks.
- Make sure the disks are not encrypted.
- Reduce periodic activity of server applications. You can do so by editing the respective timers. For more information, see Multimedia Timers.
- Close the Server Manager application on the VM.
- Disable the antivirus software. Note that disabling the antivirus might compromise the security of the VM.
- Disable the screen saver.
- Keep the Windows OS on the sign-in screen when not in use.

21.3. ENABLING STANDARD HARDWARE SECURITY ON WINDOWS VIRTUAL MACHINES

To secure Windows virtual machines (VMs), you can enable basic level security by using the standard hardware capabilities of the Windows device.

Prerequisites

- Make sure you have installed the latest WHQL certified VirtIO drivers.
- Make sure the VM's firmware supports UEFI boot.
- Install the **edk2-OVMF** package on your host machine.

  ```
  # {PackageManagerCommand} install edk2-ovmf
  ```

- Install the **vTPM** packages on your host machine.

  ```
  # {PackageManagerCommand} install swtpm libtpms
  ```

- Make sure the VM is using the Q35 machine architecture.
- Make sure you have the Windows installation media.

Procedure

1. Enable TPM 2.0 by adding the following parameters to the **<devices>** section in the VM's XML configuration.

   ```
   <devices>
   ```

```
[...]
  <tpm model='tpm-crb'>
    <backend type='emulator' version='2.0'/>
  </tpm>
[...]
</devices>
```

2. Install Windows in UEFI mode. For more information about how to do so, see Creating a SecureBoot virtual machine.

3. Install the VirtIO drivers on the Windows VM. For more information about how to do so, see Installing virtio drivers on a Windows guest .

4. In UEFI, enable Secure Boot. For more information about how to do so, see Secure Boot.

Verification

- Ensure that the **Device Security** page on your Windows machine displays the following message:
  Settings > Update & Security > Windows Security > Device Security

  ```
  Your device meets the requirements for standard hardware security.
  ```

21.4. ENABLING ENHANCED HARDWARE SECURITY ON WINDOWS VIRTUAL MACHINES

To further secure Windows virtual machines (VMs), you can enable virtualization-based protection of code integrity, also known as Hypervisor-Protected Code Integrity (HVCI).

Prerequisites

- You have RHEL 9.6 or later as your host.

- You have enabled standard hardware security. For more information, see Enabling standard hardware security on Windows virtual machines.

- You have enabled Hyper-V enlightenments. For more information, see Enabling Hyper-V enlightenments.

Procedure

1. Open the XML configuration of the Windows VM. The following example opens the configuration of the *Example-L1* VM:

   ```
   # virsh edit Example-L1
   ```

2. Under the **<cpu>** section, specify the CPU mode and add the policy flag.

IMPORTANT

- For Intel CPUs, enable the **vmx** policy flag.
- For AMD CPUs, enable the **svm** policy flag.
- If you do not wish to specify a custom CPU, you can set the **<cpu mode>** as **host-passthrough**.

```
<cpu mode='custom' match='exact' check='partial'>
  <model fallback='allow'>Skylake-Client-IBRS</model>
  <topology sockets='1' dies='1' cores='4' threads='1'/>
  <feature policy='require' name='vmx'/>
</cpu>
```

3. Save the XML configuration and reboot the VM.
4. On the VMs operating system, navigate to the **Core isolation details** page:
   Settings > Update & Security > Windows Security > Device Security > Core isolation details
5. Toggle the switch to enable **Memory Integrity**.
6. Reboot the VM.

NOTE

For other methods of enabling HVCI, see the relevant Microsoft documentation.

Verification

- Ensure that the **Device Security** page on your Windows VM displays the following message:
  Settings > Update & Security > Windows Security > Device Security

  ```
  Your device meets the requirements for enhanced hardware security.
  ```

- Alternatively, check System Information about the Windows VM:
  a. Run **msinfo32.exe** in a command prompt.
  b. Check if **Credential Guard, Hypervisor enforced Code Integrity** is listed under **Virtualization-based security Services Running**

21.5. NEXT STEPS

- To use utilities for accessing, editing, and creating virtual machine disks or other disk images for a Windows VM, install the **libguestfs-tools** and **libguestfs-winsupport** packages on the host machine:

  ```
  $ sudo dnf install libguestfs-tools libguestfs-winsupport
  ```

- To use utilities for accessing, editing, and creating virtual machine disks or other disk images for a Windows VM, install the **guestfs-tools** and **guestfs-winsupport** packages on the host machine:

```
$ sudo dnf install guestfs-tools guestfs-winsupport
```

- To share files between your RHEL 9 host and its Windows VMs, you can use virtiofs or NFS.

CHAPTER 22. CREATING NESTED VIRTUAL MACHINES

You can use nested virtual machines (VMs) if you require a different host operating system than what your local host is running. This eliminates the need for additional physical hardware.

WARNING

In most environments, nested virtualization is only available as a Technology Preview in RHEL 9.

For detailed descriptions of the supported and unsupported environments, see Support limitations for nested virtualization .

22.1. WHAT IS NESTED VIRTUALIZATION?

With nested virtualization, you can run virtual machines (VMs) within other VMs. A standard VM that runs on a physical host can also act as a second hypervisor and create its own VMs.

Nested virtualization terminology

Level 0 (L0)

A physical host, a bare-metal machine.

Level 1 (L1)

A standard VM, running on an **L0** physical host, that can act as an additional virtual host.

Level 2 (L2)

A nested VM running on an **L1** virtual host.
Important: The second level of virtualization severely limits the performance of an **L2** VM. For this reason, nested virtualization is primarily intended for development and testing scenarios, such as:

- Debugging hypervisors in a constrained environment
- Testing larger virtual deployments on a limited amount of physical resources

WARNING

In most environments, nested virtualization is only available as a Technology Preview in RHEL 9.

For detailed descriptions of the supported and unsupported environments, see Support limitations for nested virtualization .

Additional resources

- Support limitations for nested virtualization

22.2. SUPPORT LIMITATIONS FOR NESTED VIRTUALIZATION

In most environments, nested virtualization is only available as a Technology Preview in RHEL 9.

However, you can use a Windows virtual machine (VM) with the Windows Subsystem for Linux (WSL2) to create a virtual Linux environment inside the Windows VM. This use case is fully supported on RHEL 9 under specific conditions.

To learn more about the relevant terminology for nested virtualization, see What is nested virtualization?

Supported environments

To create a supported deployment of nested virtualization, create an **L1** Windows VM on a RHEL 9 **L0** host and use WSL2 to create a virtual Linux environment inside the **L1** Windows VM. Currently, this is the only supported nested environment.

IMPORTANT

The **L0** host must be an Intel or AMD system. Other architectures, such as ARM or IBM Z, are currently not supported.

You must use only the following operating system versions:

On the **L0** host:	On the **L1** VMs:
RHEL 9.2 and later	Windows Server 2019 with WSL2
	Windows Server 2022 with WSL2
	Windows 10 with WSL2
	Windows 11 with WSL2

See Microsoft documentation for instructions on installing WSL2 and choosing supported Linux distributions.

To create a supported nested environment, use one of the following procedures:

- Creating a nested virtual machine on Intel
- Creating a nested virtual machine on AMD

Technology Preview environments

These nested environments are available only as a Technology Preview and are not supported.

IMPORTANT

The **L0** host must be an Intel, AMD, or IBM Z system. Nested virtualization currently does not work on other architectures, such as ARM.

You must use only the following operating system versions:

On the **L0** host:	On the **L1** VMs:	On the **L2** VMs:
RHEL 9.2 and later	RHEL 8.8 and later	RHEL 8.8 and later
	RHEL 9.2 and later	RHEL 9.2 and later
	Windows Server 2016 with Hyper-V	Windows Server 2019
	Windows Server 2019 with Hyper-V	Windows Server 2022
	Windows Server 2022 with Hyper-V	
	Windows 10 with Hyper-V	
	Windows 11 with Hyper-V	

NOTE

Creating RHEL **L1** VMs is not tested when used in other Red Hat virtualization offerings. These include:

- Red Hat Virtualization
- Red Hat OpenStack Platform
- OpenShift Virtualization

To create a Technology Preview nested environment, use one of the following procedures:

- Creating a nested virtual machine on Intel
- Creating a nested virtual machine on AMD
- Creating a nested virtual machine on IBM Z

Hypervisor limitations

- Currently, Red Hat tests nesting only on RHEL-KVM. When RHEL is used as the **L0** hypervisor, you can use RHEL or Windows as the **L1** hypervisor.

- When using an **L1** RHEL VM on a non-KVM **L0** hypervisor, such as VMware ESXi or Amazon Web Services (AWS), creating **L2** VMs in the RHEL guest operating system has not been tested and might not work.

Feature limitations

- Use of **L2** VMs as hypervisors and creating **L3** guests has not been properly tested and is not expected to work.
- Migrating VMs currently does not work on AMD systems if nested virtualization has been enabled on the **L0** host.
- On an IBM Z system, huge-page backing storage and nested virtualization cannot be used at the same time.

```
# modprobe kvm hpage=1 nested=1
modprobe: ERROR: could not insert 'kvm': Invalid argument
# dmesg |tail -1
[90226.508366] kvm-s390: A KVM host that supports nesting cannot back its KVM guests
with huge pages
```

- Some features available on the **L0** host might be unavailable for the **L1** hypervisor.

Additional resources

- What is Windows Subsystem for Linux?
- Creating a nested virtual machine on Intel
- Creating a nested virtual machine on AMD
- Creating a nested virtual machine on IBM Z

22.3. CREATING A NESTED VIRTUAL MACHINE ON INTEL

Follow the steps below to enable and configure nested virtualization on an Intel host.

> **WARNING**
>
> In most environments, nested virtualization is only available as a Technology Preview in RHEL 9.
>
> For detailed descriptions of the supported and unsupported environments, see Support limitations for nested virtualization .

Prerequisites

- An L0 RHEL 9 host running an L1 virtual machine (VM).

- The hypervisor CPU must support nested virtualization. To verify, use the **cat /proc/cpuinfo** command on the L0 hypervisor. If the output of the command includes the **vmx** and **ept** flags, creating L2 VMs is possible. This is generally the case on Intel Xeon v3 cores and later.

- Ensure that nested virtualization is enabled on the L0 host:

  ```
  # cat /sys/module/kvm_intel/parameters/nested
  ```

  - If the command returns **1** or **Y**, the feature is enabled. Skip the remaining prerequisite steps, and continue with the Procedure section.

  - If the command returns **0** or **N** but your system supports nested virtualization, use the following steps to enable the feature.

    i. Unload the **kvm_intel** module:

    ```
    # modprobe -r kvm_intel
    ```

    ii. Activate the nesting feature:

    ```
    # modprobe kvm_intel nested=1
    ```

    iii. The nesting feature is now enabled, but only until the next reboot of the L0 host. To enable it permanently, add the following line to the **/etc/modprobe.d/kvm.conf** file:

    ```
    options kvm_intel nested=1
    ```

Procedure

1. Configure your L1 VM for nested virtualization.

   a. Open the XML configuration of the VM. The following example opens the configuration of the *Intel-L1* VM:

   ```
   # virsh edit Intel-L1
   ```

   b. Configure the VM to use **host-passthrough** CPU mode by editing the **<cpu>** element:

   ```
   <cpu mode='host-passthrough'/>
   ```

   If you require the VM to use a specific CPU model, configure the VM to use **custom** CPU mode. Inside the **<cpu>** element, add a **<feature policy='require' name='vmx'/>** element and a **<model>** element with the CPU model specified inside. For example:

   ```
   <cpu mode ='custom' match ='exact' check='partial'>
     <model fallback='allow'>Haswell-noTSX</model>
     <feature policy='require' name='vmx'/>
     ...
   </cpu>
   ```

2. Create an L2 VM within the L1 VM. To do this, follow the same procedure as when creating the L1 VM.

22.4. CREATING A NESTED VIRTUAL MACHINE ON AMD

Follow the steps below to enable and configure nested virtualization on an AMD host.

> **WARNING**
>
> In most environments, nested virtualization is only available as a Technology Preview in RHEL 9.
>
> For detailed descriptions of the supported and unsupported environments, see Support limitations for nested virtualization .

Prerequisites

- An L0 RHEL 9 host running an L1 virtual machine (VM).
- The hypervisor CPU must support nested virtualization. To verify, use the **cat /proc/cpuinfo** command on the L0 hypervisor. If the output of the command includes the **svm** and **npt** flags, creating L2 VMs is possible. This is generally the case on AMD EPYC cores and later.
- Ensure that nested virtualization is enabled on the L0 host:

  ```
  # cat /sys/module/kvm_amd/parameters/nested
  ```

  - If the command returns **1** or **Y**, the feature is enabled. Skip the remaining prerequisite steps, and continue with the Procedure section.
  - If the command returns **0** or **N**, use the following steps to enable the feature.

    i. Stop all running VMs on the L0 host.

    ii. Unload the **kvm_amd** module:

    ```
    # modprobe -r kvm_amd
    ```

    iii. Activate the nesting feature:

    ```
    # modprobe kvm_amd nested=1
    ```

    iv. The nesting feature is now enabled, but only until the next reboot of the L0 host. To enable it permanently, add the following to the **/etc/modprobe.d/kvm.conf** file:

    ```
    options kvm_amd nested=1
    ```

Procedure

1. Configure your L1 VM for nested virtualization.

   a. Open the XML configuration of the VM. The following example opens the configuration of the *AMD-L1* VM:

```
# virsh edit AMD-L1
```

b. Configure the VM to use **host-passthrough** CPU mode by editing the **<cpu>** element:

```
<cpu mode='host-passthrough'/>
```

If you require the VM to use a specific CPU model, configure the VM to use **custom** CPU mode. Inside the **<cpu>** element, add a **<feature policy='require' name='svm'/>** element and a **<model>** element with the CPU model specified inside. For example:

```
<cpu mode="custom" match="exact" check="none">
  <model fallback="allow">EPYC-IBPB</model>
  <feature policy="require" name="svm"/>
  ...
</cpu>
```

2. Create an L2 VM within the L1 VM. To do this, follow the same procedure as when creating the L1 VM.

22.5. CREATING A NESTED VIRTUAL MACHINE ON IBM Z

Follow the steps below to enable and configure nested virtualization on an IBM Z host.

NOTE

IBM Z does not really provide a bare-metal **L0** host. Instead, user systems are set up on a logical partition (LPAR), which is already a virtualized system, so it is often referred to as **L1**. However, for better alignment with other architectures in this guide, the following steps refer to IBM Z as if it provides an **L0** host.

To learn more about nested virtualization, see: What is nested virtualization?

WARNING

In most environments, nested virtualization is only available as a Technology Preview in RHEL 9.

For detailed descriptions of the supported and unsupported environments, see Support limitations for nested virtualization .

Prerequisites

- An L0 RHEL 9 host running an L1 virtual machine (VM).
- The hypervisor CPU must support nested virtualization. To verify this is the case, use the **cat /proc/cpuinfo** command on the L0 hypervisor. If the output of the command includes the **sie** flag, creating L2 VMs is possible.

- Ensure that nested virtualization is enabled on the L0 host:

  ```
  # cat /sys/module/kvm/parameters/nested
  ```

  - If the command returns **1** or **Y**, the feature is enabled. Skip the remaining prerequisite steps, and continue with the Procedure section.
  - If the command returns **0** or **N**, use the following steps to enable the feature.

    i. Stop all running VMs on the L0 host.

    ii. Unload the **kvm** module:

    ```
    # modprobe -r kvm
    ```

    iii. Activate the nesting feature:

    ```
    # modprobe kvm nested=1
    ```

    iv. The nesting feature is now enabled, but only until the next reboot of the L0 host. To enable it permanently, add the following line to the **/etc/modprobe.d/kvm.conf** file:

    ```
    options kvm nested=1
    ```

Procedure

- Create an L2 VM within the L1 VM. To do this, follow the same procedure as when creating the L1 VM.

CHAPTER 23. DIAGNOSING VIRTUAL MACHINE PROBLEMS

When working with virtual machines (VMs), you may encounter problems with varying levels of severity. Some problems may have a quick and easy fix, while for others, you may have to capture VM-related data and logs to report or diagnose the problems.

The following sections provide detailed information about generating logs and diagnosing some common VM problems, as well as about reporting these problems.

23.1. GENERATING LIBVIRT DEBUG LOGS

To diagnose virtual machine (VM) problems, it is helpful to generate and review libvirt debug logs. Attaching debug logs is also useful when asking for support to resolve VM-related problems.

The following sections explain what debug logs are, how you can set them to be persistent, enable them during runtime, and attach them when reporting problems.

23.1.1. Understanding libvirt debug logs

Debug logs are text files that contain data about events that occur during virtual machine (VM) runtime. The logs provide information about fundamental server-side functionalities, such as host libraries and the libvirt daemon. The log files also contain the standard error output (**stderr**) of all running VMs.

Debug logging is not enabled by default and has to be enabled when libvirt starts. You can enable logging for a single session or persistently. You can also enable logging when a libvirt daemon session is already running by modifying the daemon run-time settings.

Attaching the libvirt debug logs is also useful when requesting support with a VM problem.

23.1.2. Enabling persistent settings for libvirt debug logs

You can configure libvirt debug logging to be automatically enabled whenever libvirt starts. By default, **virtqemud** is the main libvirt daemon in RHEL 9. To make persistent changes in the libvirt configuration, you must edit the **virtqemud.conf** file, located in the **/etc/libvirt** directory.

NOTE

In some cases, for example when you upgrade from RHEL 8, **libvirtd** might still be the enabled libvirt daemon. In that case, you must edit the **libvirtd.conf** file instead.

Procedure

1. Open the **virtqemud.conf** file in an editor.

2. Replace or set the filters according to your requirements.

   Table 23.1. Debugging filter values

1	logs all messages generated by libvirt.
2	logs all non-debugging information.

3	logs all warning and error messages. This is the default value.
4	logs only error messages.

> **Example 23.1. Sample daemon settings for logging filters**
>
> The following settings:
>
> - Log all error and warning messages from the **remote**, **util.json**, and **rpc** layers
> - Log only error messages from the **event** layer.
> - Save the filtered logs to **/var/log/libvirt/libvirt.log**
>
> ```
> log_filters="3:remote 4:event 3:util.json 3:rpc"
> log_outputs="1:file:/var/log/libvirt/libvirt.log"
> ```

3. Save and exit.

4. Restart the libvirt daemon.

   ```
   $ systemctl restart virtqemud.service
   ```

23.1.3. Enabling libvirt debug logs during runtime

You can modify the libvirt daemon’s runtime settings to enable debug logs and save them to an output file.

This is useful when restarting the libvirt daemon is not possible because restarting fixes the problem, or because there is another process, such as migration or backup, running at the same time. Modifying runtime settings is also useful if you want to try a command without editing the configuration files or restarting the daemon.

Prerequisites

- Make sure the **libvirt-admin** package is installed.

Procedure

1. Optional: Back up the active set of log filters.

   ```
   # virt-admin -c virtqemud:///system daemon-log-filters >> virt-filters-backup
   ```

> **NOTE**
>
> It is recommended that you back up the active set of filters so that you can restore them after generating the logs. If you do not restore the filters, the messages will continue to be logged which may affect system performance.

2. Use the **virt-admin** utility to enable debugging and set the filters according to your requirements.

   Table 23.2. Debugging filter values

1	logs all messages generated by libvirt.
2	logs all non-debugging information.
3	logs all warning and error messages. This is the default value.
4	logs only error messages.

   > **Example 23.2. Sample virt-admin setting for logging filters**
   >
   > The following command:
   >
   > - Logs all error and warning messages from the **remote**, **util.json**, and **rpc** layers
   > - Logs only error messages from the **event** layer.
   >
   > ```
   > # virt-admin -c virtqemud:///system daemon-log-filters "3:remote 4:event 3:util.json 3:rpc"
   > ```

3. Use the **virt-admin** utility to save the logs to a specific file or directory.
   For example, the following command saves the log output to the **libvirt.log** file in the **/var/log/libvirt/** directory.

   ```
   # virt-admin -c virtqemud:///system daemon-log-outputs "1:file:/var/log/libvirt/libvirt.log"
   ```

4. Optional: You can also remove the filters to generate a log file that contains all VM-related information. However, it is not recommended since this file may contain a large amount of redundant information produced by libvirt’s modules.

   - Use the **virt-admin** utility to specify an empty set of filters.

     ```
     # virt-admin -c virtqemud:///system daemon-log-filters
       Logging filters:
     ```

5. Optional: Restore the filters to their original state using the backup file.
   Perform the second step with the saved values to restore the filters.

23.1.4. Attaching libvirt debug logs to support requests

You may have to request additional support to diagnose and resolve virtual machine (VM) problems. Attaching the debug logs to the support request is highly recommended to ensure that the support team has access to all the information they need to provide a quick resolution of the VM-related problem.

Procedure

- To report a problem and request support, open a support case.
- Based on the encountered problems, attach the following logs along with your report:
  - For problems with the libvirt service, attach the **/var/log/libvirt/libvirt.log** file from the host.
  - For problems with a specific VM, attach its respective log file.
    For example, for the *testguest1* VM, attach the **testguest1.log** file, which can be found at **/var/log/libvirt/qemu/testguest1.log**.

Additional resources

- How to provide log files to Red Hat Support? (Red Hat Knowledgebase)

23.2. DUMPING A VIRTUAL MACHINE CORE

To analyze why a virtual machine (VM) crashed or malfunctioned, you can dump the VM core to a file on disk for later analysis and diagnostics.

This section provides a brief introduction to core dumping and explains how you can dump a VM core to a specific file.

23.2.1. How virtual machine core dumping works

A virtual machine (VM) requires numerous running processes to work accurately and efficiently. In some cases, a running VM may terminate unexpectedly or malfunction while you are using it. Restarting the VM may cause the data to be reset or lost, which makes it difficult to diagnose the exact problem that caused the VM to crash.

In such cases, you can use the **virsh dump** utility to save (or *dump*) the core of a VM to a file before you reboot the VM. The core dump file contains a raw physical memory image of the VM which contains detailed information about the VM. This information can be used to diagnose VM problems, either manually, or by using a tool such as the **crash** utility.

Additional resources

- **crash** man page on your system
- The **crash** Github repository

23.2.2. Creating a virtual machine core dump file

A virtual machine (VM) core dump contains detailed information about the state of a VM at any given time. This information, which is similar to a snapshot of the VM, can help you detect problems if a VM malfunctions or shuts down suddenly.

Prerequisites

- Make sure you have sufficient disk space to save the file. Note that the space occupied by the VM depends on the amount of RAM allocated to the VM.

Procedure

- Use the **virsh dump** utility.

For example, the following command dumps the **lander1** VM's cores, its memory and the CPU common register file to **gargantua.file** in the **/core/file** directory.

```
# virsh dump lander1 /core/file/gargantua.file --memory-only
Domain 'lander1' dumped to /core/file/gargantua.file
```

IMPORTANT

The **crash** utility no longer supports the default file format of the virsh dump command. To analyze a core dump file by using **crash**, you must create the file with the **--memory-only** option.

Additionally, you must use the **--memory-only** option when creating a core dump file to attach to a Red Hat Support Case.

Troubleshooting

If the **virsh dump** command fails with a **System is deadlocked on memory** error, ensure you are assigning sufficient memory for the core dump file. To do so, use the following **crashkernel** option value. Alternatively, do not use **crashkernel** at all, which assigns core dump memory automatically.

```
crashkernel=1G-4G:192M,4G-64G:256M,64G-:512M
```

Additional resources

- **virsh dump --help** command
- **virsh** man page on your system
- Opening a Support Case

23.3. BACKTRACING VIRTUAL MACHINE PROCESSES

When a process related to a virtual machine (VM) malfunctions, you can use the **gstack** command along with the process identifier (PID) to generate an execution stack trace of the malfunctioning process. If the process is a part of a thread group then all the threads are traced as well.

Prerequisites

- Ensure that the **GDB** package is installed.
  For details about installing **GDB** and the available components, see Installing the GNU Debugger.
- Make sure you know the PID of the processes that you want to backtrace.
  You can find the PID by using the **pgrep** command followed by the name of the process. For example:

  ```
  # pgrep libvirt
  22014
  22025
  ```

Procedure

- Use the **gstack** utility followed by the PID of the process you wish to backtrace.
  For example, the following command backtraces the libvirt process with the PID 22014.

  ```
  # gstack 22014
  Thread 3 (Thread 0x7f33edaf7700 (LWP 22017)):
  #0  0x00007f33f81aef21 in poll () from /lib64/libc.so.6
  #1  0x00007f33f89059b6 in g_main_context_iterate.isra () from /lib64/libglib-2.0.so.0
  #2  0x00007f33f8905d72 in g_main_loop_run () from /lib64/libglib-2.0.so.0
  ...
  ```

Additional resources

- **gstack** man page on your system
- GNU Debugger (GDB)

Additional resources for reporting virtual machine problems and providing logs

To request additional help and support, you can:

- Raise a service request by using the **redhat-support-tool** command line option, the Red Hat Portal UI, or several methods of FTP.
  - To report problems and request support, see Open a Support Case .
- Upload the SOS Report and the log files when you submit a service request.
  This ensures that the Red Hat support engineer has all the necessary diagnostic information for reference.
  - For more information about SOS reports, see the Red Hat Knowledgebase solution What is an SOS Report and how to create one in Red Hat Enterprise Linux?
  - For information about attaching log files, see the Red Hat Knowledgebase solution How to provide files to Red Hat Support?

CHAPTER 24. BACKING UP AND RECOVERING VIRTUAL MACHINES

To ensure that you do not lose the setup and data of a virtual machine (VM) if your current host becomes unavailable or non-functional, back up the configuration and storage of the VM. Afterwards, for disaster recovery, you can create a new VM that uses the backed up configuration and storage.

> **NOTE**
>
> If you plan to create a backup to recover a VM while the host remains functional, it might be more efficient to use snapshots instead. For details, see Saving and restoring virtual machine state by using snapshots.

24.1. BACKING UP A VIRTUAL MACHINE

To ensure that you do not lose the setup and data of a virtual machine (VM) if your current host becomes unavailable or non-functional, back up the configuration and disks of the VM. This allows you to later recover the backup on a functional host.

Procedure

1. Save the XML configuration of the VM to a separate file. For example, to save the configration of the *testguest1* VM to the **/home/backup/testguest1-backup.xml** file, use the following command:

   ```
   # virsh dumpxml testguest1 > /home/backup/testguest1-backup.xml
   ```

2. Optional: Customize your backup settings. By default, **libvirt** creates copies of all disks in the VM in the same directory as the original disks. If you want to use a different configuration for your backup, create an XML file with your required settings. For example:

   ```
   <domainbackup>
     <disks>
       <disk name='vda' backup='yes'/>
       <disk name='vdb' type='file'>
         <target file='/home/backup/vdb.backup'/>
         <driver type='raw'/>
       </disk>
       <disk name='vdc' backup='no'/>
     </disks>
   </domainbackup>
   ```

   This example configuration ensures that the **vda** disk is backed up by using the **libvirt** defaults, the **vdb** disk is backed up in the **raw** format as **/home/backup/vdb.backup**, and that the **vdc** disk is not backed up.

3. Start the VM.

   ```
   # virsh start <vm-name>
   ```

4. Back up the disks of the VM by using the **virsh backup-begin** utility. The following command uses the default backup settings, which creates copies of all disks that the VM uses, and saves them in the same directory as the original disks

```
# virsh backup-begin <vm-name>
```

Optionally, to apply custom backup settings, you can specify the backup XML configuration that you created previously.

```
# virsh backup-begin <vm-name> --backupxml <backup-XML-location>
```

Verification

1. Ensure that the backup operation has completed.

   ```
   # virsh domjobinfo <vm-name> --completed
   ```

   Example successful output:

   ```
   Job type:         Completed
   Operation:        Backup
   Time elapsed:     20704 ms
   File processed:   40.000 GiB
   File remaining:   0.000 B
   File total:       40.000 GiB
   ```

2. Check the target location of the backup disks. For example, if you used the default backup configuration and the VM disks are located in the default **/var/lib/libvirt/images/** directory, use the following command:

   ```
   # ls -l /var/lib/libvirt/images
   ```

   Example successful output:

   ```
   -rw-------. 1 qemu qemu 42956488704 Oct 10 15:49 RHEL_10_beta.qcow2
   -rw-------. 1 root root 42956488704 Oct 29 16:12 RHEL_10_beta.qcow.21761750144
   -rw-------. 1 qemu qemu      196688 Oct 10 15:49 extra-storage.qcow2
   -rw-------. 1 root root 196688 Oct 29 16:12 extra-storage.qcow2.1761750144
   ```

Next steps

- Recovering a virtual machine

Additional resources

- Libvirt reference for backup XML format

24.2. RECOVERING A VIRTUAL MACHINE

For disaster recovery of your virtual machines (VMs), you can create a new VM that uses the XML configuration and storage that you previously backed up.

Prerequisites

- You have created a backup of the VM's XML configuration and storage. For instructions, see Backing up a virtual machine.

Procedure

1. Inspect the backup XML configuration of the VM for the specific storage settings.

   ```
   # cat </path/to/backup.xml>
   ```

   Example output section:

   ```
   <disk type='file' device='disk'>
       <driver name='qemu' type='qcow2' discard='unmap'/>
       <source file='/var/lib/libvirt/images/vm-name.qcow2' index='3'/>
   ```

2. Move the backup disks to the locations specified in the backup XML and ensure that their names correspond with the values in the XML.

3. Define a new VM based on the backup XML.

   ```
   # virsh define --file </path/to/backup.xml>
   ```

4. Optional: Modify the XML configuration of the newly created VM to adjust for settings that might be different from the original host, such as the network.

   ```
   # virsh edit <vm-name>
   ```

Verification

- Start the VM and check that the guest operating system has been recovered correctly.

  ```
  # virsh start <vm-name>
  ```

CHAPTER 25. FEATURE SUPPORT AND LIMITATIONS IN RHEL 9 VIRTUALIZATION

This document provides information about feature support and restrictions in Red Hat Enterprise Linux 9 (RHEL 9) virtualization.

25.1. HOW RHEL VIRTUALIZATION SUPPORT WORKS

A set of support limitations applies to virtualization in Red Hat Enterprise Linux 9 (RHEL 9). This means that when you use certain features or exceed a certain amount of allocated resources when using virtual machines in RHEL 9, Red Hat will provide only limited support for these guests unless you have a specific subscription plan.

Features listed in Recommended features in RHEL 9 virtualization have been tested and certified by Red Hat to work with the KVM hypervisor on a RHEL 9 system. Therefore, they are fully supported and recommended for use in virtualization in RHEL 9.

Features listed in Unsupported features in RHEL 9 virtualization may work, but are not supported and not intended for use in RHEL 9. Therefore, Red Hat strongly recommends not using these features in RHEL 9 with KVM.

Resource allocation limits in RHEL 9 virtualization lists the maximum amount of specific resources supported on a KVM guest in RHEL 9. Guests that exceed these limits are considered as Technology Preview by Red Hat.

In addition, unless stated otherwise, all features and solutions used by the documentation for RHEL 9 virtualization are supported. However, some of these have not been completely tested and therefore may not be fully optimized.

IMPORTANT

Many of these limitations do not apply to other virtualization solutions provided by Red Hat, such as OpenShift Virtualization or Red Hat OpenStack Platform (RHOSP).

25.2. RECOMMENDED FEATURES IN RHEL 9 VIRTUALIZATION

The following features are recommended for use with the KVM hypervisor included with Red Hat Enterprise Linux 9 (RHEL 9):

Host system architectures

RHEL 9 with KVM is only supported on the following host architectures:

- AMD64 and Intel 64
- IBM Z - IBM z14 systems and later
- ARM 64

Any other hardware architectures are not supported for using RHEL 9 as a KVM virtualization host, and Red Hat highly discourages doing so.

Guest operating systems

Red Hat provides support with KVM virtual machines that use specific guest operating systems (OSs). For a detailed list of certified guest OSs, see Certified Guest Operating Systems in the Red Hat KnowledgeBase.

Note, however, that by default, your guest OS does not use the same subscription as your host. Therefore, you must activate a separate licence or subscription for the guest OS to work properly.

In addition, the pass-through devices that you attach to the VM must be supported by both the host OS and the guest OS.

Similarly, for optimal function of your deployment, Red Hat recommends that the CPU model and features that you define in the XML configuration of a VM are supported by both the host OS and the guest OS.

To view the certified CPUs and other hardware for various versions of RHEL, see the Red Hat Ecosystem Catalog.

Machine types

To ensure that your VM is compatible with your host architecture and that the guest OS runs optimally, the VM must use an appropriate machine type.

IMPORTANT

In RHEL 9, **pc-i440fx-rhel7.5.0** and earlier machine types, which were default in earlier major versions of RHEL, are no longer supported. As a consequence, attempting to start a VM with such machine types on a RHEL 9 host fails with an **unsupported configuration** error. If you encounter this problem after upgrading your host to RHEL 9, see the Red Hat Knowledgebase solution Invalid virtual machines that used to work with RHEL 9 and newer hypervisors.

When creating a VM by using the command line , the **virt-install** utility provides multiple methods of setting the machine type.

- When you use the **--os-variant** option, **virt-install** automatically selects the machine type recommended for your host CPU and supported by the guest OS.
- If you do not use **--os-variant** or require a different machine type, use the **--machine** option to specify the machine type explicitly.
- If you specify a **--machine** value that is unsupported or not compatible with your host, **virt-install** fails and displays an error message.

The recommended machine types for KVM virtual machines on supported architectures, and the corresponding values for the **--machine** option, are as follows. *Y* stands for the latest minor version of RHEL 9.

- On **Intel 64 and AMD64** (x86_64): **pc-q35-rhel9.*Y*.0** → **--machine=q35**
- On **IBM Z** (s390x): **s390-ccw-virtio-rhel9.*Y*.0** → **--machine=s390-ccw-virtio**
- On **ARM 64**: **virt-rhel9.*Y*.0** → **--machine=virt**

To obtain the machine type of an existing VM:

```
# virsh dumpxml VM-name | grep machine=
```

-

To view the full list of machine types supported on your host:

```
# /usr/libexec/qemu-kvm -M help
```

Additional resources

- Unsupported features in RHEL 9 virtualization
- Resource allocation limits in RHEL 9 virtualization

25.3. UNSUPPORTED FEATURES IN RHEL 9 VIRTUALIZATION

The following features are not supported by the KVM hypervisor included with Red Hat Enterprise Linux 9 (RHEL 9):

> **IMPORTANT**
>
> Many of these limitations may not apply to other virtualization solutions provided by Red Hat, such as OpenShift Virtualization or Red Hat OpenStack Platform (RHOSP).
>
> Features supported by other virtualization solutions are described below.
>
> For support details of the respective virtualization solutions, consult the relevant documentation.

Host system architectures

RHEL 9 with KVM is not supported on any host architectures that are not listed in Recommended features in RHEL 9 virtualization.

Guest operating systems

KVM virtual machines (VMs) that use the following guest operating systems (OSs) are not supported on a RHEL 9 host:

- Windows 8.1 and earlier
- Windows Server 2012 R2 and earlier
- macOS
- Solaris for x86 systems
- Any operating system released before 2009

For a list of guest OSs supported on RHEL hosts and other virtualization solutions, see Certified Guest Operating Systems in Red Hat OpenStack Platform, Red Hat Virtualization, OpenShift Virtualization and Red Hat Enterprise Linux with KVM.

Creating VMs in containers

Red Hat does not support creating KVM virtual machines in any type of container that includes the elements of the RHEL 9 hypervisor (such as the **QEMU** emulator or the **libvirt** package).

To create VMs in containers, Red Hat recommends using the OpenShift Virtualization offering.

Specific virsh commands and options

Not every parameter that you can use with the **virsh** utility has been tested and certified as production-ready by Red Hat. Therefore, any **virsh** commands and options that are not explicitly recommended by Red Hat documentation may not work correctly, and Red Hat recommends not using them in your production environment.

Notably, unsupported **virsh** commands include the following:

- **virsh iface-*** commands, such as **virsh iface-start** and **virsh iface-destroy**
- **virsh blkdeviotune**
- **virsh snapshot-*** commands that do not support *external* snapshots. For details, see Support limitations for virtual machine snapshots.

The QEMU command line

QEMU is an essential component of the virtualization architecture in RHEL 9, but it is difficult to manage manually, and improper QEMU configurations might cause security vulnerabilities. Therefore, using **qemu-*** command-line utilities, such as, **qemu-kvm** is not supported by Red Hat. Instead, use *libvirt* utilities, such as **virt-install**, **virt-xml**, and supported **virsh** commands, as these orchestrate QEMU according to the best practices. However, the **qemu-img** utility is supported for management of virtual disk images.

vCPU hot unplug

Removing a virtual CPU (vCPU) from a running VM, also referred to as a vCPU hot unplug, is not supported in RHEL 9. Note that adding vCPUs to a running VM, or vCPU hot plug, is supported.

QEMU-side I/O throttling

Using the **virsh blkdeviotune** utility to configure maximum input and output levels for operations on virtual disk, also known as QEMU-side I/O throttling, is not supported in RHEL 9.

To set up I/O throttling in RHEL 9, use **virsh blkiotune**. This is also known as libvirt-side I/O throttling. For instructions, see Disk I/O throttling in virtual machines .

Other solutions:

- QEMU-side I/O throttling is also supported in RHOSP. For more information, see Red Hat Knowledgebase solutions Setting Resource Limitation on Disk and the **Use Quality-of-Service Specifications** section in the RHOSP Storage Guide.
- In addition, OpenShift Virtualizaton supports QEMU-side I/O throttling as well.

Storage live migration

Moving the disk of a VM to another location while the VM is running on a single host, for example by using the **virsh blockcopy** command, is not supported in RHEL 9.

Note, however, that migrating a VM along with its storage, for example by using the **virsh migrate --live --copy-storage-all** command, is supported.

Other solutions:

- Storage live migration is supported in RHOSP, but with some limitations. For details, see Migrate a Volume.

vHost Data Path Acceleration

On RHEL 9 hosts, it is possible to configure vHost Data Path Acceleration (vDPA) for virtio devices, but Red Hat currently does not support this feature, and strongly discourages its use in production environments.

vhost-user

RHEL 9 does not support the implementation of a **vhost-user** interface.

S3 and S4 system power states

Suspending a VM to the **Suspend to RAM** (S3) or **Suspend to disk** (S4) system power states is not supported. Note that these features are disabled by default, and enabling them will make your VM not supportable by Red Hat.

Note that the S3 and S4 states are also currently not supported in any other virtualization solution provided by Red Hat.

virtio-crypto

Using the *virtio-crypto* device in RHEL 9 is not supported and RHEL strongly discourages its use.

Note that *virtio-crypto* devices are also not supported in any other virtualization solution provided by Red Hat.

virtio-multitouch-device, virtio-multitouch-pci

Using the *virtio-multitouch-device* and *virtio-multitouch-pci* devices in RHEL 9 is not supported and RHEL strongly discourages their use.

Incremental live backup

Configuring a VM backup that only saves VM changes since the last backup, also known as incremental live backup, is not supported in RHEL 9, and Red Hat highly discourages its use.

Other solutions:

- Use 3rd party backup solutions instead.

net_failover

Using the **net_failover** driver to set up an automated network device failover mechanism is not supported in RHEL 9.

Note that **net_failover** is also currently not supported in any other virtualization solution provided by Red Hat.

TCG

QEMU and libvirt include a dynamic translation mode using the QEMU Tiny Code Generator (TCG). This mode does not require hardware virtualization support. However, TCG is not supported by Red Hat.

TCG-based guests can be recognized by examining its XML configuration, for example using the **virsh dumpxml** command.

- The configuration file of a TCG guest contains the following line:

  ```
  <domain type='qemu'>
  ```

- The configuration file of a KVM guest contains the following line:

  ```
  <domain type='kvm'>
  ```

SR-IOV InfiniBand networking devices

Attaching InfiniBand networking devices to VMs using Single-root I/O virtualization (SR-IOV) is not supported.

Additional resources

- Recommended features in RHEL 9 virtualization
- Resource allocation limits in RHEL 9 virtualization

25.4. RESOURCE ALLOCATION LIMITS IN RHEL 9 VIRTUALIZATION

The following limits apply to virtualized resources that can be allocated to a single KVM virtual machine (VM) on a Red Hat Enterprise Linux 9 (RHEL 9) host. If you VM exceeds these limits, it is considered a Technology Preview by Red Hat.

IMPORTANT

Many of these limitations do not apply to other virtualization solutions provided by Red Hat, such as OpenShift Virtualization or Red Hat OpenStack Platform (RHOSP).

Maximum vCPUs per VM

For the maximum amount of vCPUs and memory that is supported on a single VM running on a RHEL 9 host, see: Virtualization limits for Red Hat Enterprise Linux with KVM

PCI devices per VM

RHEL 9 supports **32** PCI device slots per VM bus, and **8** PCI functions per device slot. This gives a theoretical maximum of 256 PCI functions per bus when multi-function capabilities are enabled in the VM, and no PCI bridges are used.

Each PCI bridge adds a new bus, potentially enabling another 256 device addresses. However, some buses do not make all 256 device addresses available for the user; for example, the root bus has several built-in devices occupying slots.

Virtualized IDE devices

KVM is limited to a maximum of **4** virtualized IDE devices per VM.

25.5. SUPPORTED DISK IMAGE FORMATS

To run a virtual machine (VM) on RHEL, you must use a disk image with a supported format. You can also convert certain unsupported disk images to a supported format.

Supported disk image formats for VMs

You can use disk images that use the following formats to run VMs in RHEL:

- **qcow2** - Provides certain additional features, such as compression.

- **raw** - Might provide better performance.
- **luks** - Disk images encrypted by using the Linux Unified Key Setup (LUKS) specification.

Supported disk image formats for conversion

- If required, you can convert your disk images between the **raw** and **qcow2** formats by using the **qemu-img convert** command.
- If you require converting a **vmdk** disk image to a **raw** or **qcow2** format, convert the VM that uses the disk to KVM by using the **virt-v2v** utility.
- To convert other disk image formats to **raw** or **qcow2**, you can use the **qemu-img convert** command. For a list of formats that work with this command, see the QEMU documentation. Note that in most cases, converting the disk image format of a non-KVM virtual machine to **qcow2** or **raw** is not sufficient for the VM to correctly run on RHEL KVM. In addition to converting the disk image, corresponding drivers must be installed and configured in the guest operating system of the VM. For supported hypervisor conversion, use the **virt-v2v** utility.

Additional resources

- Converting virtual machines from other hypervisors to KVM with virt-v2v in RHEL 7, RHEL 8, and RHEL 9
- Converting between virtual disk image formats

25.6. HOW VIRTUALIZATION ON IBM Z DIFFERS FROM AMD64 AND INTEL 64

KVM virtualization in RHEL 9 on IBM Z systems differs from KVM on AMD64 and Intel 64 systems in the following:

PCI and USB devices

Virtual PCI and USB devices are not supported on IBM Z. This also means that **virtio-*-pci** devices are unsupported, and **virtio-*-ccw** devices should be used instead. For example, use **virtio-net-ccw** instead of **virtio-net-pci**.
Note that direct attachment of PCI devices, also known as PCI passthrough, is supported.

Supported guest operating system

Red Hat only supports VMs hosted on IBM Z if they use RHEL 7, 8, or 9 as their guest operating system.

Device boot order

IBM Z does not support the **<boot dev='*device*'>** XML configuration element. To define device boot order, use the **<boot order='*number*'>** element in the **<devices>** section of the XML.

> **NOTE**
>
> Using **<boot order='*number*'>** for boot order management is recommended on all host architectures.

In addition, you can select the required boot entry by using the architecture-specific **loadparm** attribute in the **<boot>** element. For example, the following determines that the disk should be used first in the boot sequence and if a Linux distribution is available on that disk, it will select the second boot entry:

```
<disk type='file' device='disk'>
  <driver name='qemu' type='qcow2'/>
  <source file='/path/to/qcow2'/>
  <target dev='vda' bus='virtio'/>
  <address type='ccw' cssid='0xfe' ssid='0x0' devno='0x0000'/>
  <boot order='1' loadparm='2'/>
</disk>
```

Memory hot plug

Adding memory to a running VM is not possible on IBM Z. Note that removing memory from a running VM (*memory hot unplug*) is also not possible on IBM Z, as well as on AMD64 and Intel 64.

NUMA topology

Non-Uniform Memory Access (NUMA) topology for CPUs is not supported by **libvirt** on IBM Z. Therefore, tuning vCPU performance by using NUMA is not possible on these systems.

GPU devices

Assigning GPU devices is not supported on IBM Z systems.

vfio-ap

VMs on an IBM Z host can use the *vfio-ap* cryptographic device passthrough, which is not supported on any other architecture.

vfio-ccw

VMs on an IBM Z host can use the *vfio-ccw* disk device passthrough, which is not supported on any other architecture.

SMBIOS

SMBIOS configuration is not available on IBM Z.

Live VM memory dumps

Creating a memory dump of a VM might fail on IBM Z when using the **--live** option. In rare cases, creating a VM snapshot might also fail. To prevent these issues, use RHEL 9.8 or later on the host and avoid using the **--live** option.

Watchdog devices

If using watchdog devices in your VM on an IBM Z host, use the **diag288** model. For example:

```
<devices>
  <watchdog model='diag288' action='poweroff'/>
</devices>
```

kvm-clock

The **kvm-clock** service is specific to AMD64 and Intel 64 systems, and does not have to be configured for VM time management on IBM Z.

v2v and p2v

The **virt-v2v** and **virt-p2v** utilities are supported only on the AMD64 and Intel 64 architecture, and are not provided on IBM Z.

Migrations

To successfully migrate to a later host model (for example from IBM z14 to z15), or to update the hypervisor, use the **host-model** CPU mode. The **host-passthrough** and **maximum** CPU modes are not recommended, as they are generally not migration-safe.
If you want to specify an explicit CPU model in the **custom** CPU mode, follow these guidelines:

- Do not use CPU models that end with **-base**.
- Do not use the **qemu**, **max** or **host** CPU model.

To successfully migrate to an older host model (such as from z15 to z14), or to an earlier version of QEMU, KVM, or the RHEL kernel, use the CPU type of the oldest available host model without **-base** at the end.

- If you have both the source host and the destination host running, you can instead use the **virsh hypervisor-cpu-baseline** command on the destination host to obtain a suitable CPU model. For details, see Verifying host CPU compatibility for virtual machine migration .
- For more information about supported machine types in RHEL 9, see Recommended features in RHEL 9 virtualization.

PXE installation and booting

When using PXE to run a VM on IBM Z, a specific configuration is required for the **pxelinux.cfg/default** file. For example:

```
# pxelinux
default linux
label linux
kernel kernel.img
initrd initrd.img
append ip=dhcp inst.repo=example.com/redhat/BaseOS/s390x/os/
```

Secure Execution

You can boot a VM with a prepared secure guest image by defining **<launchSecurity type="s390-pv"/>** in the XML configuration of the VM. This encrypts the VM's memory to protect it from unwanted access by the hypervisor.

Note that the following features are not supported when running a VM in secure execution mode:

- Device passthrough by using **vfio**
- Obtaining memory information by using **virsh domstats** and **virsh memstat**
- The **memballoon** and **virtio-rng** virtual devices
- Memory backing by using huge pages
- Live and non-live VM migrations
- Saving and restoring VMs
- VM snapshots, including memory snapshots (using the **--memspec** option)
- Full memory dumps. Instead, specify the **--memory-only** option for the **virsh dump** command.

- 248 or more vCPUs. The vCPU limit for secure guests is 247.

Additional resources

- An overview of virtualization features support across architectures

25.7. HOW VIRTUALIZATION ON ARM 64 DIFFERS FROM AMD64 AND INTEL 64

KVM virtualization in RHEL 9 on ARM 64 systems (also known as AArch64) is different from KVM on AMD64 and Intel 64 systems in several aspects. These include, but are not limited to, the following:

Guest operating systems

The only guest operating systems currently supported on ARM 64 virtual machines (VMs) is RHEL 9 or RHEL 10.

vCPU hot plug and hot unplug

Attaching a virtual CPU (vCPU) to a running VM, also referred to as a vCPU hot plug, is currently not supported on ARM 64 hosts. In addition, like on AMD64 and Intel 64 hosts, removing a vCPU from a running VM (vCPU hot unplug), is not supported on ARM 64.

SecureBoot

The SecureBoot feature is not available on ARM 64 systems.

Migration

Migrating VMs between ARM 64 hosts is supported only if the source and destination host use the same CPU, firmware, and memory page size.

Memory page sizes

ARM 64 currently supports running VMs with 64 KB or 4 KB memory page sizes, however both the host and the guest must use the same memory page size. Configurations where host and guest have different memory page sizes are not supported.

By default, RHEL 9 uses a 4 KB memory page size. If you want to run a VM with a 64 KB memory page size, your host must be using a kernel with 64 KB memory page size . When creating the VM, you must install it with the **kernel-64k package**, for example by including the following parameter in the kickstart file:

```
%packages
-kernel
kernel-64k
%end
```

Huge pages

ARM 64 hosts with 64 KB memory page size support huge memory pages with the following sizes:

- 2 MB
- 512 MB
- 16 GB

  When you use transparent huge pages (THP) on an ARM 64 host with 64 KB memory page size, it supports only 512 MB huge pages.

  ARM 64 hosts with 4 KB memory page size support huge memory pages with the following sizes:

- 64 KB
- 2 MB
- 32 MB
- 1024 MB
  When you use transparent huge pages (THP) on an ARM 64 host with 4 KB memory page size, it supports only 2 MB huge pages.

SVE

The ARM 64 architecture provides the Scalable Vector Expansion (SVE) feature. If the host supports the feature, using SVE in your VMs improves the speed of vector mathematics computation and string operations in these VMs.
The base-line level of SVE is enabled by default on host CPUs that support it. However, Red Hat recommends configuring each vector length explicitly. This ensures that the VM can only be launched on compatible hosts. To do so:

1. Verify that your CPU has the SVE feature:

   ```
   # grep -m 1 Features /proc/cpuinfo | grep -w sve

   Features: fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp cpuid
   asimdrdm fcma dcpop sve
   ```

   If the output of this command includes **sve** or if its exit code is 0, your CPU supports SVE.

2. Open the XML configuration of the VM you want to modify:

   ```
   # virsh edit vm-name
   ```

3. Edit the **<cpu>** element similarly to the following:

   ```
   <cpu mode='host-passthrough' check='none'>
   <feature policy='require' name='sve'/>
   <feature policy='require' name='sve128'/>
   <feature policy='require' name='sve256'/>
   <feature policy='disable' name='sve384'/>
   <feature policy='require' name='sve512'/>
   </cpu>
   ```

   This example explicitly enables SVE vector lengths 128, 256, and 512, and explicitly disables vector length 384.

CPU models

VMs on ARM 64 currently only support the **host-passthrough** CPU model.

PXE

Booting in the Preboot Execution Environment (PXE) is functional but not supported, Red Hat strongly discourages using it in production environments.
If you require PXE booting, it is only possible with the **virtio-net-pci** network interface controller (NIC).

EDK2

ARM 64 guests use UEFI firmware included in the **edk2-aarch64** package, which provides a similar interface as OVMF UEFI on AMD64 and Intel 64, and implements a similar set of features. Specifically, **edk2-aarch64** provides a built-in UEFI shell, but does not support the following functionality:

- SecureBoot
- Management Mode

kvm-clock

The **kvm-clock** service does not have to be configured for time management in VMs on ARM 64.

Peripheral devices

ARM 64 systems support a partly different set of peripheral devices than AMD64 and Intel 64 devices.

- Only PCIe topologies are supported.
- ARM 64 systems support **virtio** devices by using the **virtio-*-pci** drivers. As such, only **virtio-pci** devices are supported.
- The **virtio-gpu** driver is only supported for graphical installs.
- ARM 64 systems support **usb-mouse** and **usb-tablet** devices for graphical installs only. Other USB devices, USB passthrough, or USB redirect are not supported.

Emulated devices

The following devices are not supported on ARM 64:

- Emulated sound devices, such as ICH9, ICH6 or AC97.
- Emulated graphics cards, such as VGA cards.
- Emulated network devices, such as **rtl8139**.

GPU devices

Assigning GPU devices is currently not supported on ARM 64 systems.

Nested virtualization

Creating nested VMs is currently not possible on ARM 64 hosts.

v2v and p2v

The **virt-v2v** and **virt-p2v** utilities are only supported on the AMD64 and Intel 64 architecture and are, therefore, not provided on ARM 64.

25.8. AN OVERVIEW OF VIRTUALIZATION FEATURES SUPPORT IN RHEL 9

The following tables provide comparative information about the support state of selected virtualization features in RHEL 9 across the available system architectures.

Table 25.1. General support

Intel 64 and AMD64	IBM Z	ARM 64
Supported	Supported	Supported

Table 25.2. Device hot plug and hot unplug

	Intel 64 and AMD64	IBM Z	ARM 64
CPU hot plug	Supported	Supported	*UNSUPPORTED*
CPU hot unplug	*UNSUPPORTED*	*UNSUPPORTED*	*UNSUPPORTED*
Memory hot plug with virtio-mem [a]	Supported	Supported	Supported
Memory hot unplug with virtio-mem [b]	Supported	Supported	Supported
Peripheral device hot plug	Supported	Supported [c]	Supported
Peripheral device hot unplug	Supported	Supported [d]	Supported

[a] Requires using the **virtio-mem** device to hot plug memory

[b] Requires using the **virtio-mem** device to hot unplug memory

[c] Requires using **virtio- *-ccw** devices instead of **virtio- *-pci**

[d] Requires using **virtio- *-ccw** devices instead of **virtio- *-pci**

Table 25.3. Other selected features

	Intel 64 and AMD64	IBM Z	ARM 64
NUMA tuning	Supported	*UNSUPPORTED*	Supported
SR-IOV devices	Supported	*UNSUPPORTED*	Supported
virt-v2v and p2v	Supported	*UNSUPPORTED*	*UNAVAILABLE*

Note that some of the unsupported features are supported on other Red Hat products, such as Red Hat Virtualization and Red Hat OpenStack platform. For more information, see Unsupported features in RHEL 9 virtualization.

Additional sources

- Unsupported features in RHEL 9 virtualization