Red Hat

# Red Hat Enterprise Linux 8

## Configuring and managing virtualization

Setting up your host, creating and administering virtual machines, and understanding virtualization features in Red Hat Enterprise Linux 8

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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, IBM POWER, and IBM Z

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# MAKING OPEN SOURCE MORE INCLUSIVE

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright's message .

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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 8: its basics, advantages, components, and other possible virtualization solutions provided by Red Hat.

## 1.1. WHAT IS VIRTUALIZATION?

RHEL 8 provides the *virtualization* functionality, which enables a machine running RHEL 8 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 try out virtualization in Red Hat Enterprise Linux 8, see Getting started with virtualization.
- In addition to Red Hat Enterprise Linux 8 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 8 host system.

> **NOTE**
>
> Not all operating systems are supported as a guest OS in a RHEL 8 host. For details, see Recommended features in RHEL 8 virtualization .

## 1.3. VIRTUAL MACHINE COMPONENTS AND THEIR INTERACTION

Virtualization in RHEL 8 consists of the following principal software components:

### Hypervisor

The basis of creating virtual machines (VMs) in RHEL 8 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

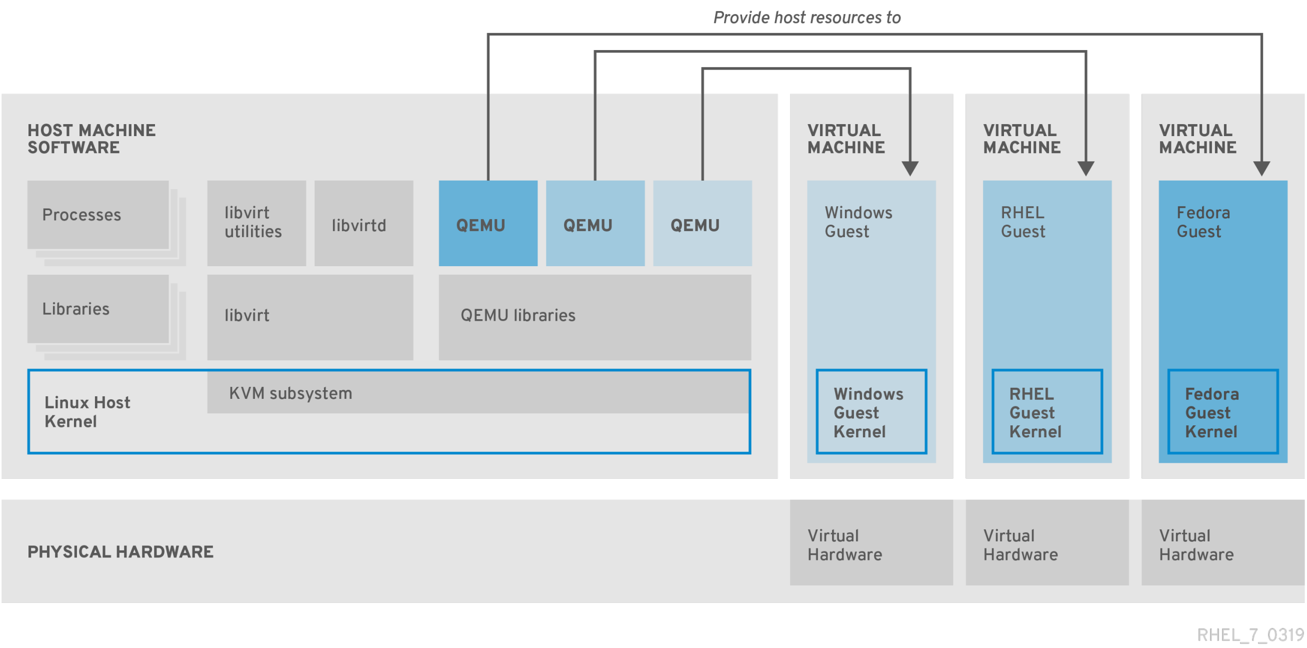
When a VM is started, the hypervisor uses the XML configuration to create an instance of the VM as a user-space process on the host. The hypervisor also makes the VM process accessible to the host-based interfaces, such as the **virsh**, **virt-install**, and **guestfish** utilities, or the web console 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 8 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 8 virtualization architecture**




## 1.4. TOOLS AND INTERFACES FOR VIRTUALIZATION MANAGEMENT

You can manage virtualization in RHEL 8 by using the command-line interface (CLI) or several graphical user interfaces (GUIs).

### Command-line interface

The CLI is the most powerful method of managing virtualization in RHEL 8. 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.

- **virt-install** - A CLI utility for creating new VMs. For more information, see the **virt-install(1)** man page.
- **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.

### Graphical interfaces

You can use the following GUIs to manage virtualization in RHEL 8:

- The **RHEL 8 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.
- The Virtual Machine Manager (**virt-manager**) application provides a specialized GUI for managing VMs and virtualization hosts.

  **IMPORTANT**

  Although still supported in RHEL 8, **virt-manager** has been deprecated. The web console is intended to become its replacement in a subsequent release. It is, therefore, recommended that you get familiar with the web console for managing virtualization in a GUI.

  However, in RHEL 8, some features may only be accessible from either **virt-manager** or the command line. For details, see Differences between virtualization features in Virtual Machine Manager and the web console.

- The **Gnome Boxes** application is a lightweight graphical interface to view and access VMs and remote systems. Gnome Boxes is primarily designed for use on desktop systems.

  **IMPORTANT**

  **Gnome Boxes** is provided as a part of the GNOME desktop environment and is supported on RHEL 8, but Red Hat recommends that you use the web console for managing virtualization in a GUI.

### Additional resources

- Getting started with virtualization

## 1.5. RED HAT VIRTUALIZATION SOLUTIONS

The following Red Hat products are built on top of RHEL 8 virtualization features and expand the KVM virtualization capabilities available in RHEL 8. In addition, many limitations of RHEL 8 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 8 virtualization

# CHAPTER 2. GETTING STARTED WITH VIRTUALIZATION

To start using virtualization in RHEL 8 , follow the steps below. The default method for this is using the command-line interface (CLI), but for user convenience, some of the steps can be completed in the web console GUI.

1. Enable the virtualization module and install the virtualization packages - see Enabling virtualization.
2. Create a virtual machine (VM):
   - For CLI, see Creating virtual machines by using the command-line interface .
   - For GUI, see Creating virtual machines and installing guest operating systems by using the web console.
3. Start the VM:
   - For CLI, see Starting a virtual machine by using the command-line interface .
   - For GUI, see Starting virtual machines by using the web console .
4. Connect to the VM:
   - For CLI, see Connecting to a virtual machine by using SSH or Opening a virtual machine graphical console by using Virt Viewer.
   - For GUI, see Interacting with virtual machines by using the web console .

**NOTE**

The web console currently provides only a subset of VM management functions, so using the command line is recommended for advanced use of virtualization in RHEL 8.

## 2.1. ENABLING VIRTUALIZATION

To use virtualization in RHEL 8, you must enable the virtualization module, install virtualization packages, and ensure your system is configured to host virtual machines (VMs).

**Prerequisites**

- RHEL 8 is installed and registered on your host machine.
- Your system meets the following hardware requirements to work as a virtualization host:
  - 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.
  - The architecture of your host machine supports KVM virtualization.

- Notably, RHEL 8 does not support virtualization on the 64-bit ARM architecture (ARM 64).
- The procedure below applies to the AMD64 and Intel 64 architecture (x86_64). To enable virtualization on a host with a different supported architecture, see one of the following sections:
  - Enabling virtualization on IBM POWER
  - Enabling virtualization on IBM Z

### Procedure

1. Install the packages in the RHEL 8 virtualization module:

```
# yum module install virt
```

2. Install the **virt-install** and **virt-viewer** packages:

```
# yum install virt-install virt-viewer
```

3. Start the **libvirtd** service:

```
# systemctl start libvirtd
```

### 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. Review the return values of **virt-host-validate** checks and take appropriate actions:
   a. If all **virt-host-validate** checks return the **PASS** value, your system is prepared for creating VMs.
   b. If any of the checks return a **FAIL** value, follow the displayed instructions to fix the problem.
   c. 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.

## 2.2. CREATING VIRTUAL MACHINES

To create a virtual machine (VM) in RHEL 8, use the command-line interface or the RHEL 8 web console.

### 2.2.1. Creating virtual machines by using the command-line interface

To create a virtual machine (VM) on your RHEL 8 host by using the **virt-install** utility, follow the instructions below.

#### 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 may 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 8. If you select a CD-ROM or DVD-ROM as the installation source when using any VM installation method available in RHEL 8, the installation will fail. For more information, see the Red Hat Knowledgebase.

  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

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

> **NOTE**
>
> The listed commands use the VNC remote display protocol instead of the default SPICE protocol. VNC currently does not have some of the features that SPICE does, but is fully supported on RHEL 9. As a result, VMs that use VNC will not stop working if you migrate your host to RHEL 9. For more information, see Considerations in adopting RHEL 9 .

- 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 \
    --graphics vnc \
    --name demo-guest1 --memory 2048 \
    --vcpus 2 --disk size=80 --os-variant win10 \
    --cdrom /home/username/Downloads/Win10install.iso
```

- The following command creates a VM named **demo-guest2** that uses the **/home/username/Downloads/rhel8.iso** image to run a RHEL 8 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 \
    --graphics vnc \
    --name demo-guest2 --memory 4096 --vcpus 4 \
    --disk none --livecd --os-variant rhel8.0 \
    --cdrom /home/username/Downloads/rhel8.iso
```

- The following command creates a RHEL 8 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 \
    --graphics vnc \
    --name demo-guest3 --memory 2048 --vcpus 2 \
    --os-variant rhel8.0 --import \
    --disk /home/username/backup/disk.qcow2
```

Note that the **--os-variant** option is highly recommended when importing a disk image. If it is not provided, the performance of the created VM will be negatively affected.

- 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 \
   --graphics vnc \
   --name demo-guest4 --memory 2048 --vcpus 2 --disk size=160 \
   --os-variant rhel8.0 --location http://example.com/OS-install \
   --initrd-inject /home/username/ks.cfg --extra-args="inst.ks=file:/ks.cfg console=tty0
console=ttyS0,115200n8"
```

- The following command creates a VM named **demo-guest5** that installs from a **RHEL8.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 \
   --os-variant rhel8.0 --location RHEL8.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 --os-variant rhel8.0 --location RHEL8.iso \
   --graphics none --extra-args='console=ttyS0'
```

### 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**

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

### 2.2.2. Creating virtual machines and installing guest operating systems by using the web console

To manage virtual machines (VMs) in a GUI on a RHEL 8 host, use the web console. The following sections provide information about how to use the RHEL 8 web console to create VMs and install guest operating systems on them.

**IMPORTANT**

VMs created by using the web console currently use the SPICE remote desktop protocol by default. However, SPICE is unsupported on RHEL 9, so if you upgrade your host to RHEL 9, the VM will stop working. For more information, see Considerations in adopting RHEL 9.

To create a VM that uses the VNC protocol, which will work correctly on RHEL 9, use the command-line interface.

#### 2.2.2.1. Creating virtual machines by using the web console

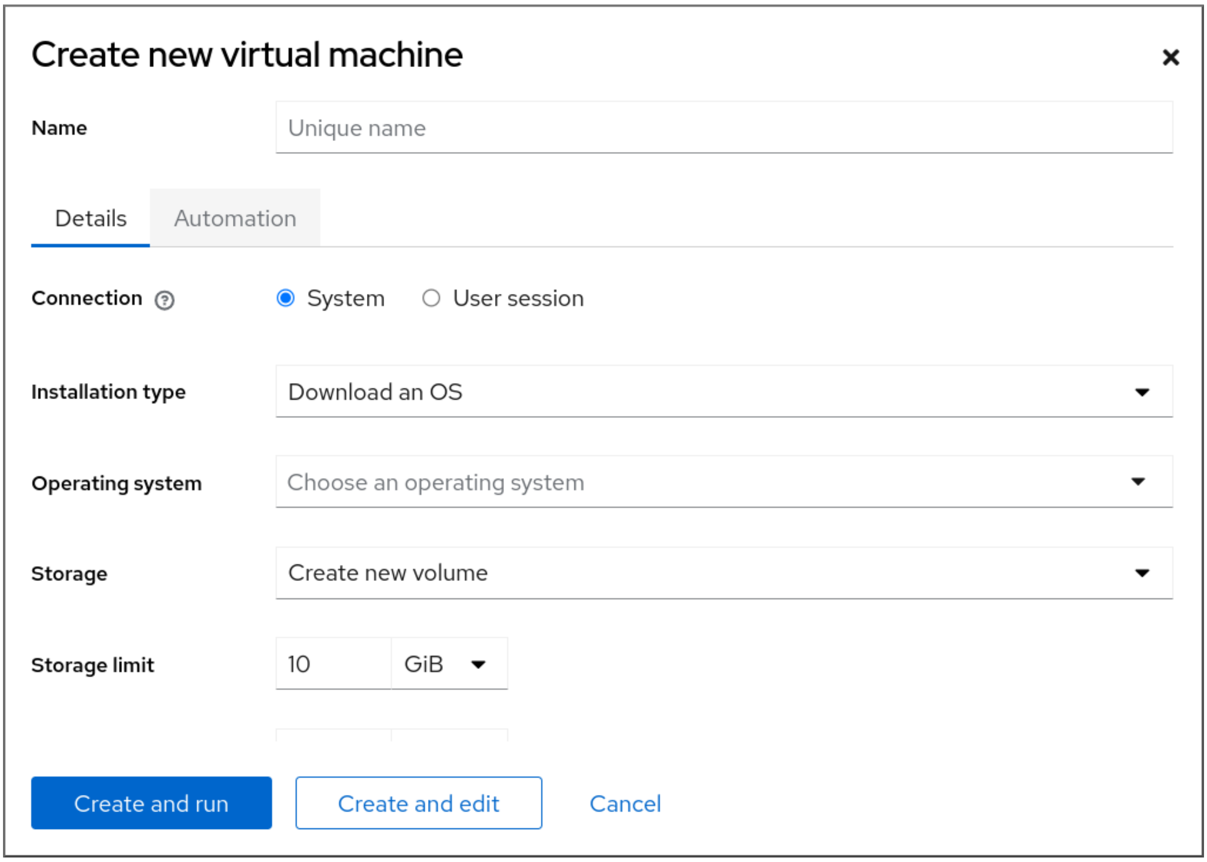
To create a virtual machine (VM) on a host machine to which your RHEL 8 web console is connected, use the instructions below.

**Prerequisites**

- 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.




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 interface

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

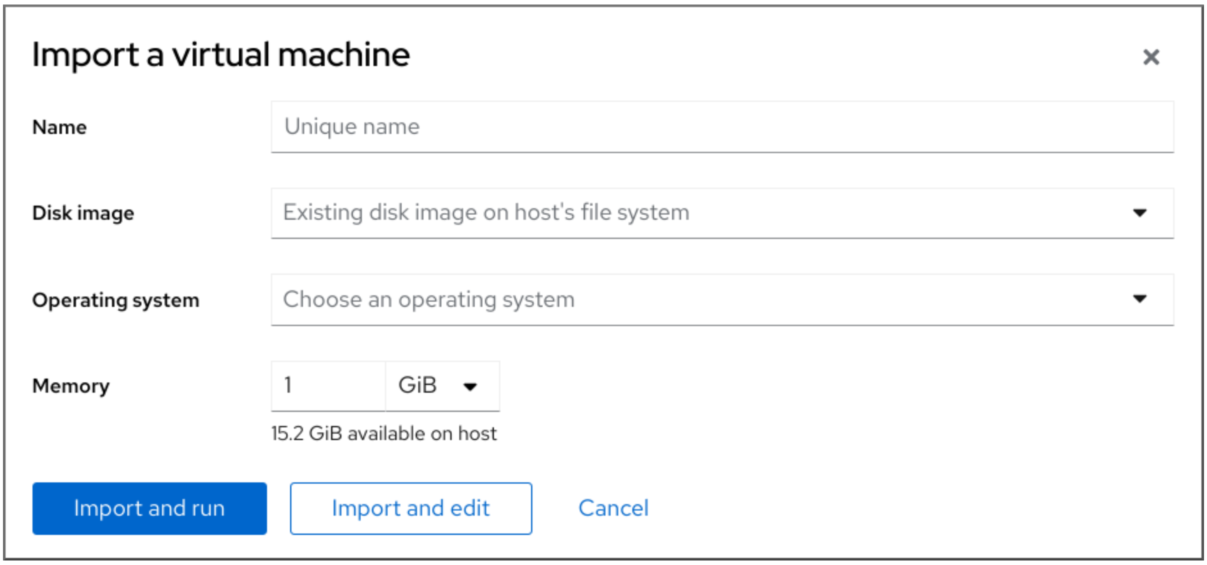
You can create a virtual machine (VM) by importing a disk image of an existing VM installation in the RHEL 8 web console.

#### Prerequisites

- 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.




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**.

#### 2.2.2.3. 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.

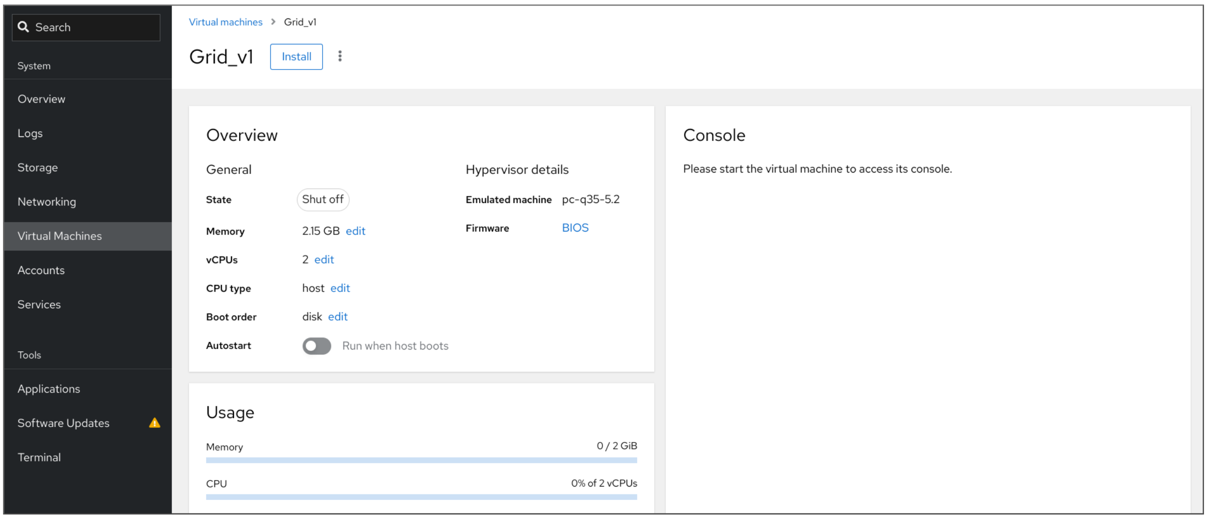
> **NOTE**
>
> If you click **Create and run** or **Import and run** while creating a new VM, the installation routine for the operating system starts automatically when the VM is created.

**Prerequisites**

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

**Procedure**

1. 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.




2. **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.


   a. Click the firmware.

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

   c. Click **Save**.

3. 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.

## 2.2.3. 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.

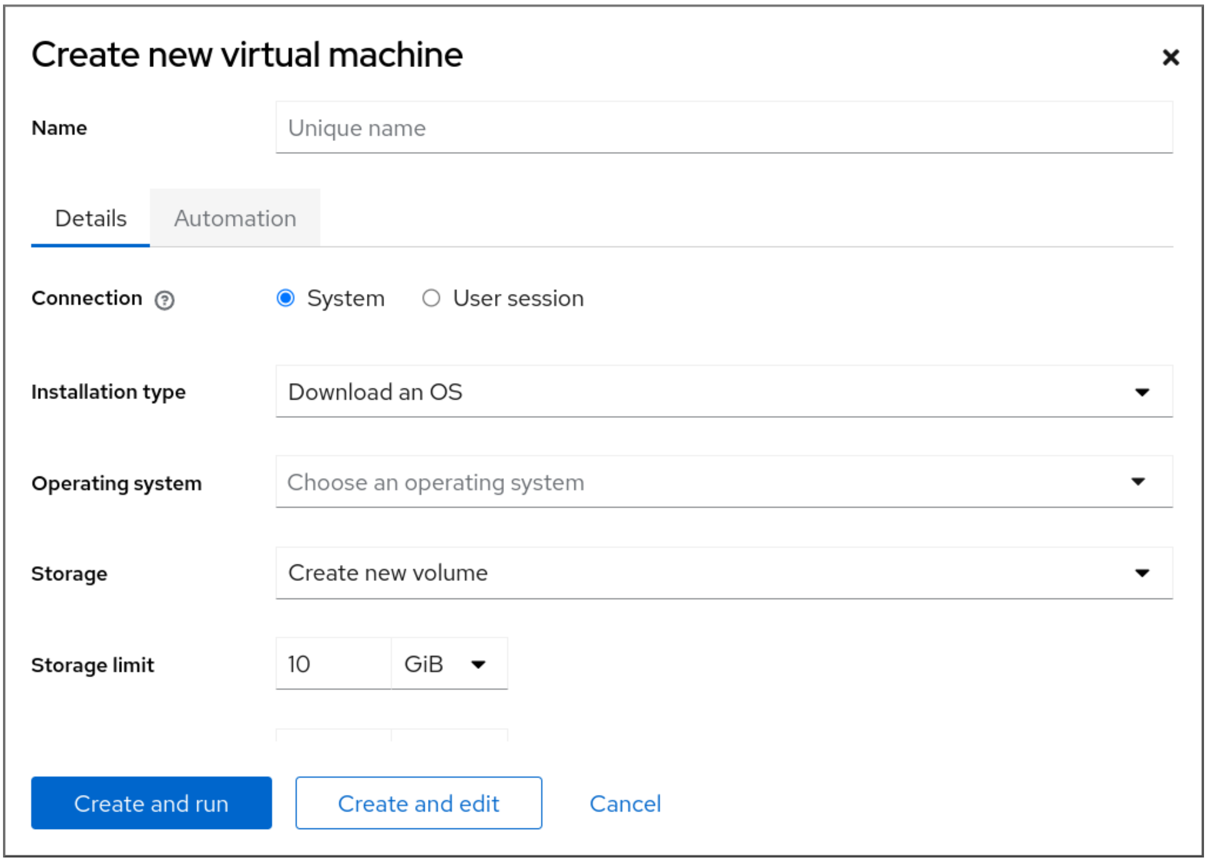
### Prerequisites

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

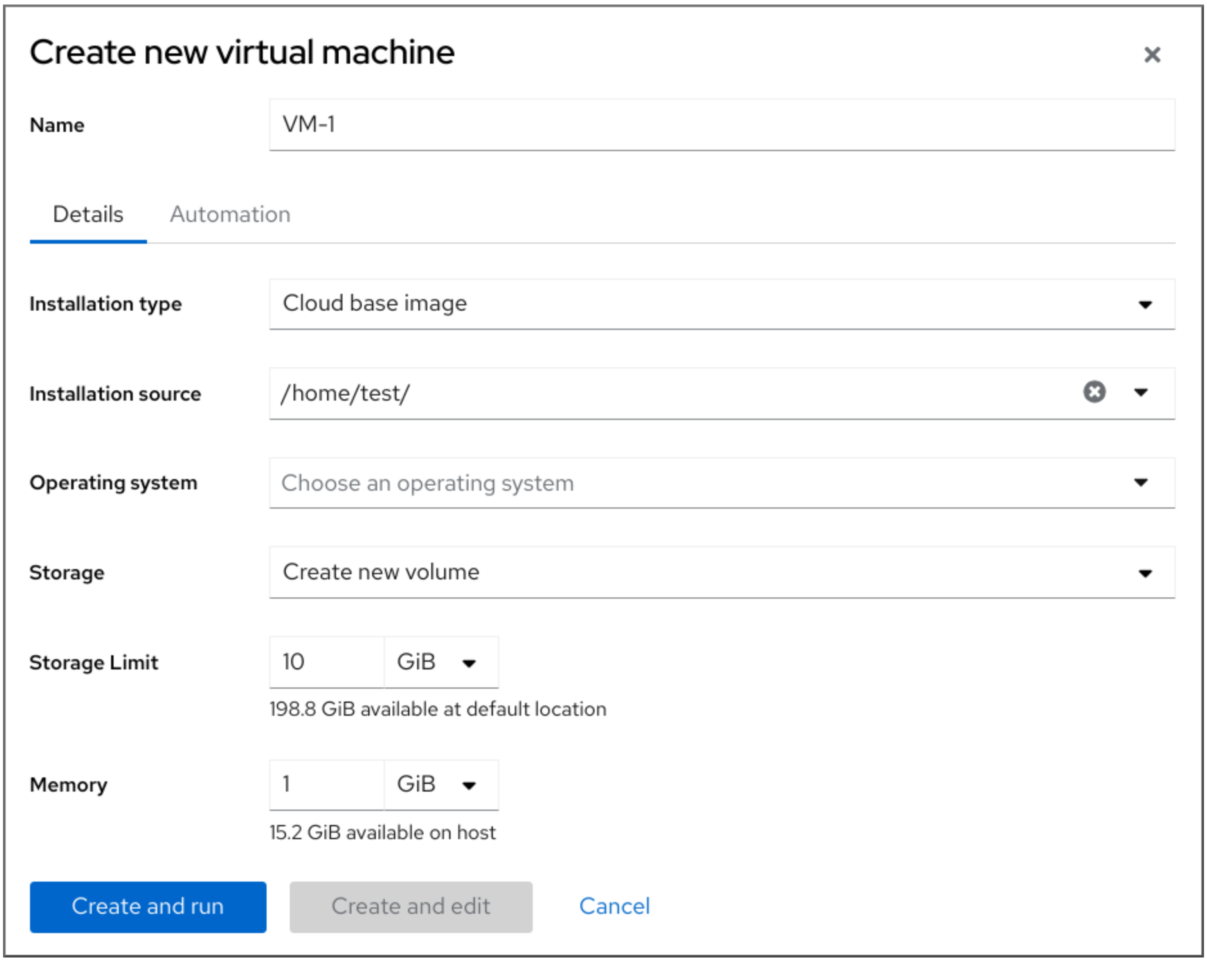
- Virtualization is enabled on your host system.
- You have a sufficient amount of system resources to allocate to your VMs, such as disk space, RAM, or CPUs. The recommended values may vary significantly depending on the intended tasks and workload of the VMs.

### Procedure

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




2. In the **Name** field, enter a name for the VM.
3. On the **Details** tab, in the **Installation type** field, select **Cloud base image**



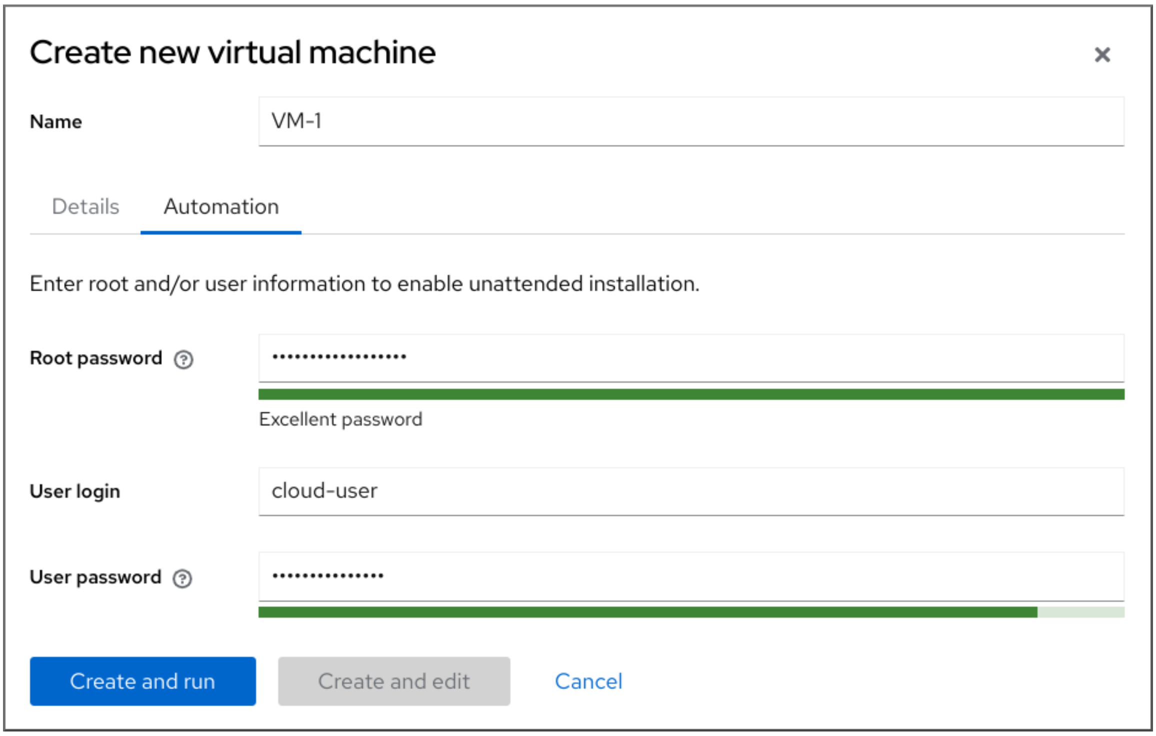

4. In the **Installation source** field, set the path to the image file on your host system.

5. 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.

6. 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.




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

### Additional resources

- Installing an operating system on a VM

## 2.3. STARTING VIRTUAL MACHINES

To start a virtual machine (VM) in RHEL 8, you can use the command line interface 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.

### 2.3.1. Starting a virtual machine by using the command-line interface

You can use the command line interface (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

## 2.3.2. 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 8 web console. You can also configure the VM to be started automatically when the host starts.

### Prerequisites

- 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

### 2.3.3. 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 **libvirtd.service.d** directory if it does not exist yet.

```
# mkdir -p /etc/systemd/system/libvirtd.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 libvirtd service.

```
# touch /etc/systemd/system/libvirtd.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 **libvirtd** 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/libvirtd.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 .

## 2.4. CONNECTING TO VIRTUAL MACHINES

To interact with a virtual machine (VM) in RHEL 8, 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.

## 2.4.1. Interacting with virtual machines by using the web console

To interact with a virtual machine (VM) in the RHEL 8 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.

### 2.4.1.1. 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 8 web console.

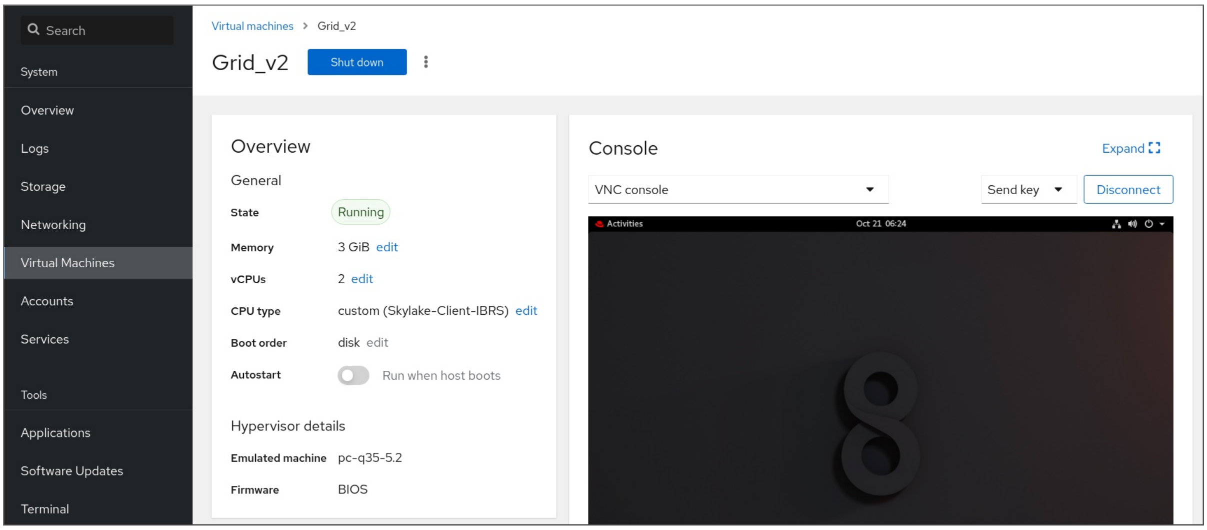
### Prerequisites

- 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. 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.
2. 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.




3. 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

## 2.4.1.2. 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 and SPICE remote viewers can be launched manually.

### Prerequisites

- 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.

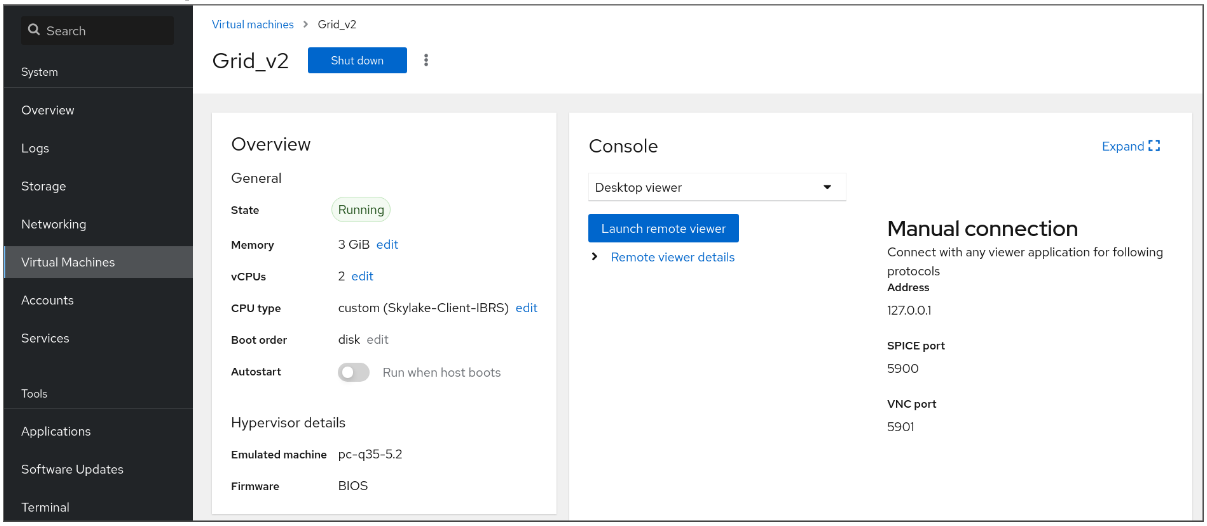
NOTE

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. 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.

2. Select **Desktop Viewer** in the console drop down menu.




3. 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** or the **spice_listen** parameter in **/etc/libvirt/qemu.conf** to change it to the host's IP address.
  - **SPICE port** - 5900
  - **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

#### 2.4.1.3. 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 8 web console. This is useful when the host machine or the VM is not configured with a graphical interface.

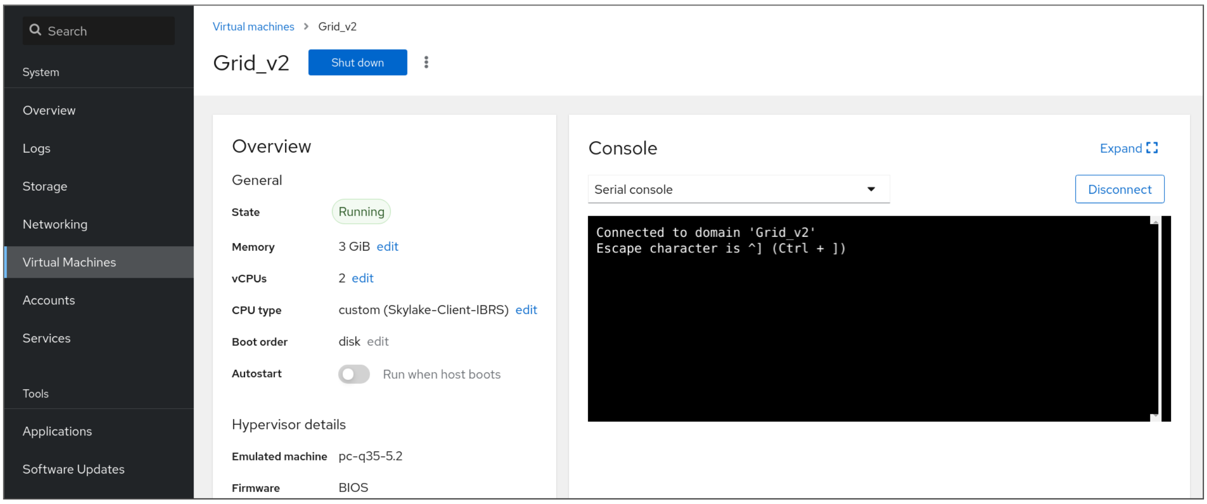
For more information about the serial console, see Opening a virtual machine serial console .

**Prerequisites**

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

**Procedure**

1. 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.
2. Select **Serial console** in the console drop down menu.
The graphical console appears in the web interface.




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

### 2.4.2. 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

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

### 2.4.3. 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:

  ```
  # yum 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 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

### 2.4.4. 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 or SPICE 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 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=ttyS0*. For example:

  ```
  # 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.

#### 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**

- The **virsh** man page

### 2.4.5. Setting up easy 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
  - Kerberos authentication in Identity Management
- The **-c** (or **--connect**) option can be used to run the **virt-install**, **virt-viewer**, **virsh** and **virt-manager** commands on a remote host.

## 2.5. SHUTTING DOWN VIRTUAL MACHINES

To shut down a running virtual machine hosted on RHEL 8, use the command line interface or the web console GUI.

### 2.5.1. Shutting down a virtual machine by using the command-line interface

To shut down a responsive virtual machine (VM), do one of the following:

- Use a shutdown command appropriate to the guest OS while connected to the guest .
- 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
    ```

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 VM instance of the VM, similarly to pulling the power cord from a physical machine. As such, 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.

### 2.5.2. Shutting down and restarting virtual machines by using the web console

Using the RHEL 8 web console, you can shut down or restart running virtual machines. You can also send a non-maskable interrupt to an unresponsive virtual machine.

#### 2.5.2.1. 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 8 web console.

**Prerequisites**

- 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

#### 2.5.2.2. 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 8 web console.

**Prerequisites**

- 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

### 2.5.2.3. 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

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

#### Procedure

1. In the **Virtual Machines** interface, find the row of the VM to which you want to send an NMI.
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 **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

## 2.6. DELETING VIRTUAL MACHINES

To delete virtual machines in RHEL 8, use the command line interface or the web console GUI.

### 2.6.1. Deleting virtual machines by using the command line interface

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

- The **virsh undefine --help** command
- The **virsh** man page

### 2.6.2. Deleting virtual machines by using the web console

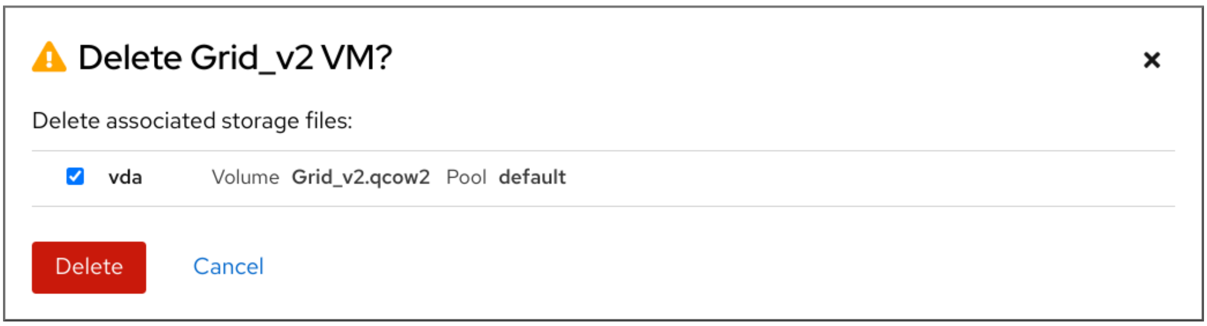
To delete a virtual machine (VM) and its associated storage files from the host to which the RHEL 8 web console is connected with, follow the procedure below:

#### Prerequisites

- 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. 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.
2. Click **Delete**.
   A confirmation dialog appears.




3. **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.
4. Click **Delete**.

The VM and any selected storage files are deleted.

**Additional resources**

- Getting started with virtualization on IBM POWER
- Getting started with virtualization on IBM Z

# CHAPTER 3. GETTING STARTED WITH VIRTUALIZATION ON IBM POWER

You can use KVM virtualization when using RHEL 8 on IBM POWER8 or POWER9 hardware. However, enabling the KVM hypervisor on your system requires extra steps compared to virtualization on AMD64 and Intel64 architectures. Certain RHEL 8 virtualization features also have different or restricted functionality on IBM POWER.

Apart from the information in the following sections, using virtualization on IBM POWER works the same as on AMD64 and Intel 64. Therefore, you can see other RHEL 8 virtualization documentation for more information when using virtualization on IBM POWER.

## 3.1. ENABLING VIRTUALIZATION ON IBM POWER

To set up a KVM hypervisor and create virtual machines (VMs) on an IBM POWER8 or IBM POWER9 system running RHEL 8, follow the instructions below.

### Prerequisites

- RHEL 8 is installed and registered on your host machine.
- 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 CPU machine type must support IBM POWER virtualization.
  To verify this, query the platform information in your **/proc/cpuinfo** file.

  ```
  # grep ^platform /proc/cpuinfo/
  platform        : PowerNV
  ```

  If the output of this command includes the **PowerNV** entry, you are running a PowerNV machine type and can use virtualization on IBM POWER.

### Procedure

1. Load the KVM-HV kernel module

   ```
   # modprobe kvm_hv
   ```

2. Verify that the KVM kernel module is loaded

   ```
   # lsmod | grep kvm
   ```

   If KVM loaded successfully, the output of this command includes **kvm_hv**.

3. Install the packages in the virtualization module:

```
# yum module install virt
```

4. Install the **virt-install** package:

```
# yum install virt-install
```

5. Start the **libvirtd** service.

```
# systemctl start libvirtd
```

#### Verification

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

```
# 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 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.

## 3.2. HOW VIRTUALIZATION ON IBM POWER DIFFERS FROM AMD64 AND INTEL 64

KVM virtualization in RHEL 8 on IBM POWER systems is different from KVM on AMD64 and Intel 64 systems in a number of aspects, notably:

#### Memory requirements

VMs on IBM POWER consume more memory. Therefore, the recommended minimum memory allocation for a virtual machine (VM) on an IBM POWER host is 2GB RAM.

**Display protocols**

The SPICE protocol is not supported on IBM POWER systems. To display the graphical output of a VM, use the **VNC** protocol. In addition, only the following virtual graphics card devices are supported:

- **vga** - only supported in **-vga std** mode and not in **-vga cirrus** mode.
- **virtio-vga**
- **virtio-gpu**

**SMBIOS**

SMBIOS configuration is not available.

**Memory allocation errors**

POWER8 VMs, including compatibility mode VMs, may fail with an error similar to:

```
qemu-kvm: Failed to allocate KVM HPT of order 33 (try smaller maxmem?): Cannot allocate memory
```

This is significantly more likely to occur on VMs that use RHEL 7.3 and prior as the guest OS.

To fix the problem, increase the CMA memory pool available for the guest's hashed page table (HPT) by adding **kvm_cma_resv_ratio=*memory*** to the host's kernel command line, where *memory* is the percentage of the host memory that should be reserved for the CMA pool (defaults to 5).

**Huge pages**

Transparent huge pages (THPs) do not provide any notable performance benefits on IBM POWER8 VMs. However, IBM POWER9 VMs can benefit from THPs as expected.
In addition, the size of static huge pages on IBM POWER8 systems are 16 MiB and 16 GiB, as opposed to 2 MiB and 1 GiB on AMD64, Intel 64, and IBM POWER9. As a consequence, to migrate a VM configured with static huge pages from an IBM POWER8 host to an IBM POWER9 host, you must first set up 1GiB huge pages on the VM.

**kvm-clock**

The **kvm-clock** service does not have to be configured for time management in VMs on IBM POWER9.

**pvpanic**

IBM POWER9 systems do not support the **pvpanic** device. However, an equivalent functionality is available and activated by default on this architecture. To enable it in a VM, use the **<on_crash>** XML configuration element with the **preserve** value.
In addition, make sure to remove the **<panic>** element from the **<devices>** section, as its presence can lead to the VM failing to boot on IBM POWER systems.

**Single-threaded host**

On IBM POWER8 systems, the host machine must run in **single-threaded mode** to support VMs. This is automatically configured if the *qemu-kvm* packages are installed. However, VMs running on single-threaded hosts can still use multiple threads.

**Peripheral devices**

A number of peripheral devices supported on AMD64 and Intel 64 systems are not supported on IBM POWER systems, or a different device is supported as a replacement.

- Devices used for PCI-E hierarchy, including **ioh3420** and **xio3130-downstream**, are not supported. This functionality is replaced by multiple independent PCI root bridges provided by the **spapr-pci-host-bridge** device.
- UHCI and EHCI PCI controllers are not supported. Use OHCI and XHCI controllers instead.
- IDE devices, including the virtual IDE CD-ROM (**ide-cd**) and the virtual IDE disk (**ide-hd**), are not supported. Use the **virtio-scsi** and **virtio-blk** devices instead.
- Emulated PCI NICs (**rtl8139**) are not supported. Use the **virtio-net** device instead.
- Sound devices, including **intel-hda**, **hda-output**, and **AC97**, are not supported.
- USB redirection devices, including **usb-redir** and **usb-tablet**, are not supported.

v2v and p2v

The **virt-v2v** and **virt-p2v** utilities are only supported on the AMD64 and Intel 64 architecture, and are not provided on IBM POWER.

### Additional sources

- For a comparison of selected supported and unsupported virtualization features across system architectures supported by Red Hat, see An overview of virtualization features support in RHEL 8.

# CHAPTER 4. GETTING STARTED WITH VIRTUALIZATION ON IBM Z

You can use KVM virtualization when using RHEL 8 on IBM Z hardware. However, enabling the KVM hypervisor on your system requires extra steps compared to virtualization on AMD64 and Intel 64 architectures. Certain RHEL 8 virtualization features also have different or restricted functionality on IBM Z.

Apart from the information in the following sections, using virtualization on IBM Z works the same as on AMD64 and Intel 64. Therefore, you can see other RHEL 8 virtualization documentation for more information when using virtualization on IBM Z.

> **NOTE**
>
> Running KVM on the z/VM OS is not supported.

## 4.1. ENABLING VIRTUALIZATION ON IBM Z

To set up a KVM hypervisor and create virtual machines (VMs) on an IBM Z system running RHEL 8, follow the instructions below.

### Prerequisites

- RHEL 8.6 or later is installed and registered on your host machine.

  > **IMPORTANT**
  >
  > If you already enabled virtualization on an IBM Z machine by using RHEL 8.5 or earlier, you should instead reconfigure your virtualization module and update your system. For instructions, see How virtualization on IBM Z differs from AMD64 and Intel 64.

- 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 a z13 CPU or later.
- RHEL 8 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. Load the KVM kernel module:

```
# modprobe kvm
```

2. Verify that the KVM kernel module is loaded:

```
# lsmod | grep kvm
```

If KVM loaded successfully, the output of this command includes **kvm**.

3. Install the packages in the **virt:rhel/common** module:

```
# yum module install virt:rhel/common
```

4. 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.

## 4.2. UPDATING VIRTUALIZATION ON IBM Z FROM RHEL 8.5 TO RHEL 8.6 OR LATER

If you installed RHEL 8 on IBM Z hardware prior to RHEL 8.6, you had to obtain virtualization RPMs from the AV stream, separate from the base RPM stream of RHEL 8. Starting with RHEL 8.6, virtualization RPMs previously available only from the AV stream are available on the base RHEL stream. In addition, the AV stream will be discontinued in a future minor release of RHEL 8. Therefore, using the AV stream is no longer recommended.

By following the instructions below, you will deactivate your AV stream and enable your access to virtualization RPMs available in RHEL 8.6 and later versions.

### Prerequisites

- You are using a RHEL 8.5 on IBM Z, with the **virt:av** module installed. To confirm that this is the case:

```
# hostnamectl | grep "Operating System"
Operating System: Red Hat Enterprise Linux 8.5 (Ootpa)
# yum module list --installed
[...]
Advanced Virtualization for RHEL 8 IBM Z Systems (RPMs)
Name      Stream     Profiles      Summary
virt      av [e]     common [i]    Virtualization module
```

### Procedure

1. Disable the **virt:av** module.

```
# yum disable virt:av
```

2. Remove the pre-existing virtualization packages and modules that your system already contains.

```
# yum module reset virt -y
```

3. Upgrade your packages to their latest RHEL versions.

```
# yum update
```

   This also automatically enables the **virt:rhel** module on your system.

### Verification

- Ensure the **virt** module on your system is provided by the **rhel** stream.

```
# yum module info virt

Name       : virt
Stream     : rhel [d][e][a]
Version    : 8050020211203195115
[...]
```

### Additional resources

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

## 4.3. HOW VIRTUALIZATION ON IBM Z DIFFERS FROM AMD64 AND INTEL 64

KVM virtualization in RHEL 8 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.
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>
```

NOTE

By using **<boot order='*number*'>** for boot order management is also preferred on AMD64 and Intel 64 hosts.

**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.

**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.

**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.

**Nested virtualization**

Creating nested VMs requires different settings on IBM Z than on AMD64 and Intel 64. For details, see Creating nested virtual machines.

**No graphical output in earlier releases**

When using RHEL 8.3 or an earlier minor version on your host, displaying the VM graphical output is not possible when connecting to the VM by using the VNC protocol. This is because the **gnome-desktop** utility was not supported in earlier RHEL versions on IBM Z. In addition, the SPICE display protocol does not work 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 8, see Recommended features in RHEL 8 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.
- Nested virtualization

**Additional resources**

- An overview of virtualization features support across architectures

## 4.4. NEXT STEPS

- When setting up a VM on an IBM Z system, it is recommended to protect the guest OS from the "Spectre" vulnerability. To do so, use the **virsh edit** command to modify the VM's XML configuration and configure its CPU in one of the following ways:
  - Use the host CPU model:

    ```
    <cpu mode='host-model' check='partial'>
      <model fallback='allow'/>
    </cpu>
    ```

    This makes the **ppa15** and **bpb** features available to the guest if the host supports them.
  - If using a specific host model, add the **ppa15** and **pbp** features. The following example uses the zEC12 CPU model:

```
<cpu mode='custom' match='exact' check='partial'>
    <model fallback='allow'>zEC12</model>
    <feature policy='force' name='ppa15'/>
    <feature policy='force' name='bpb'/>
</cpu>
```

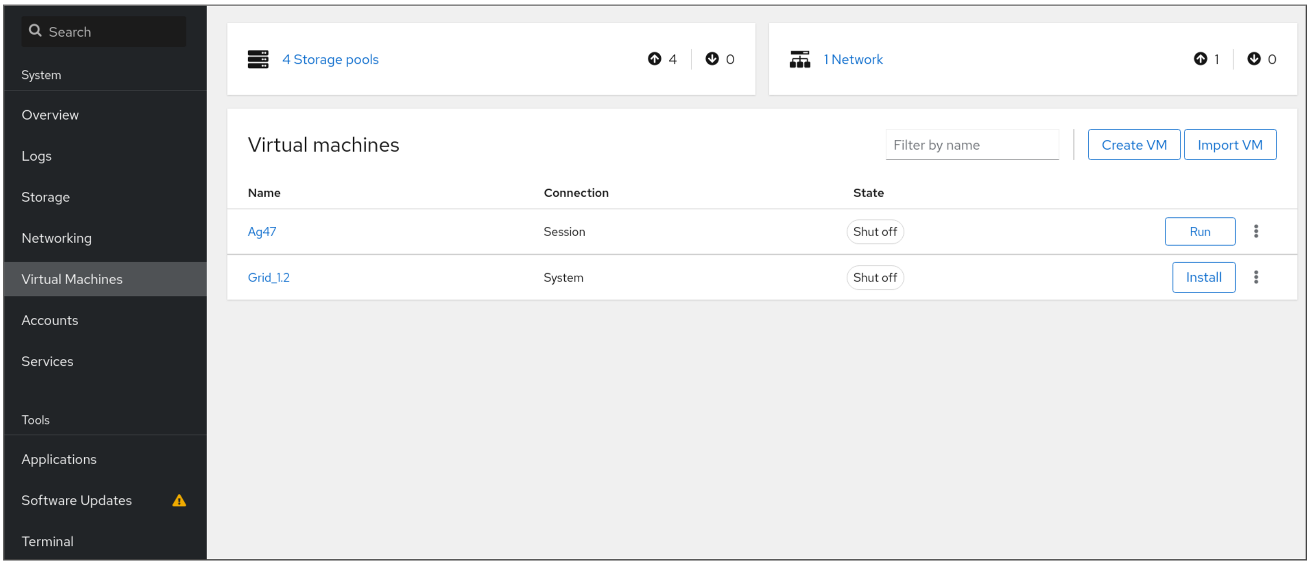
Note that when using the **ppa15** feature with the **z114** and **z196** CPU models on a host machine that uses a z12 CPU, you also need to use the latest microcode level (bundle 95 or later).

## 4.5. ADDITIONAL RESOURCES

- Attaching DASD devices to virtual machines on IBM Z
- Attaching cryptographic coprocessors to virtual machines on IBM Z
- Setting up IBM Secure Execution on IBM Z
- Creating a nested virtual machine on IBM Z
- Configuring passthrough PCI devices on IBM Z

# CHAPTER 5. MANAGING VIRTUAL MACHINES IN THE WEB CONSOLE

To manage virtual machines in a graphical interface on a RHEL 8 host, you can use the **Virtual Machines** pane in the RHEL 8 web console.




## 5.1. OVERVIEW OF VIRTUAL MACHINE MANAGEMENT BY USING THE WEB CONSOLE

The RHEL 8 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 8, 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.
- For a list of features that are currently not available in the web console but can be used in the **virt-manager** application, see Differences between virtualization features in Virtual Machine Manager and the web console.

## 5.2. SETTING UP THE WEB CONSOLE TO MANAGE VIRTUAL MACHINES

Before using the RHEL 8 web console to manage virtual machines (VMs), you must install the web console virtual machine plug-in on the host.

### Prerequisites

- Ensure that the web console is installed and enabled on your machine.

  ```
  # systemctl status cockpit.socket
  cockpit.socket - Cockpit Web Service Socket
  Loaded: loaded (/usr/lib/systemd/system/cockpit.socket
  [...]
  ```

  If this command returns **Unit cockpit.socket could not be found**, follow the Installing the web console document to enable the web console.

### Procedure

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

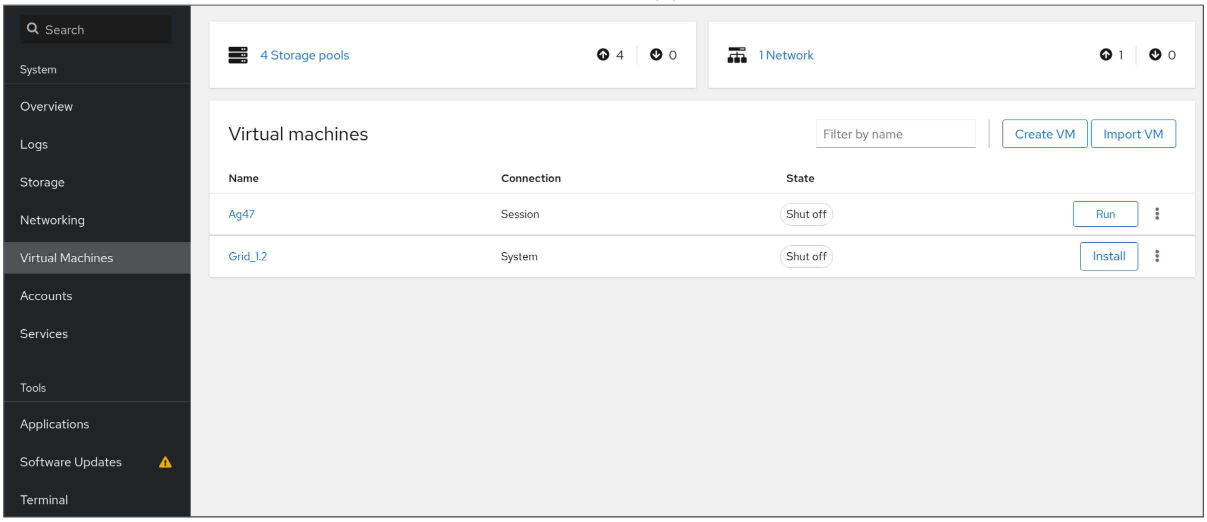
  ```
  # yum install cockpit-machines
  ```

### Verification

1. Access the web console, for example by entering the **https://localhost:9090** address in your browser.

2. Log in.

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




### Additional resources

- Managing systems by using the RHEL 8 web console

## 5.3. 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

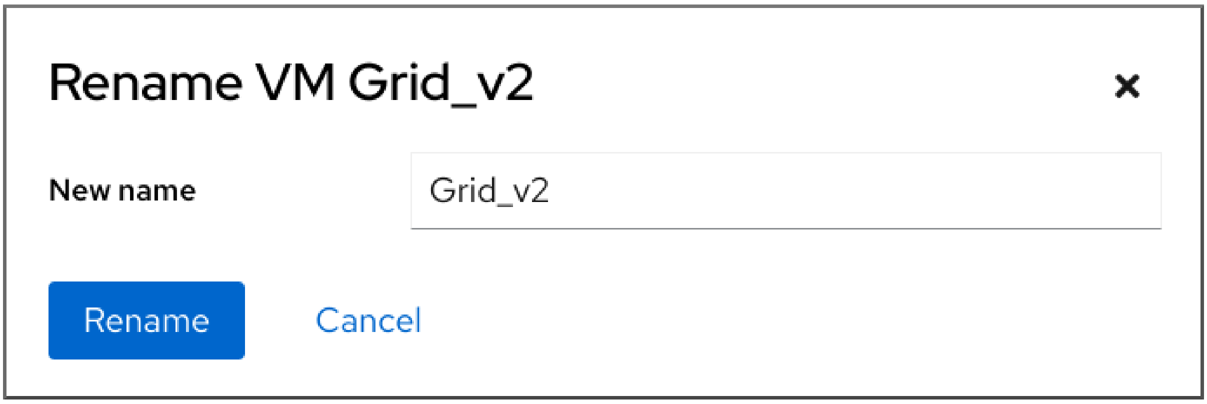
- The web console VM plug-in is installed on your system.

- 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.




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.

## 5.4. VIRTUAL MACHINE MANAGEMENT FEATURES AVAILABLE IN THE WEB CONSOLE

By using the RHEL 8 web console, you can perform the following actions to manage the virtual machines (VMs) on your system.

**Table 5.1. VM management tasks that you can perform in the RHEL 8 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 |
|---|---|
| Adjust the host memory allocated to a VM | Adding and removing virtual machine memory by using the web console |
| 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 |

## 5.5. DIFFERENCES BETWEEN VIRTUALIZATION FEATURES IN VIRTUAL MACHINE MANAGER AND THE WEB CONSOLE

The Virtual Machine Manager (**virt-manager**) application is supported in RHEL 8, but has been deprecated. The web console is intended to become its replacement in a subsequent major release. It is, therefore, recommended that you get familiar with the web console for managing virtualization in a GUI.

However, in RHEL 8, some VM management tasks can only be performed in **virt-manager** or the command line. The following table highlights the features that are available in **virt-manager** but not available in the RHEL 8.0 web console.

If a feature is available in a later minor version of RHEL 8, the minimum RHEL 8 version appears in the *Support in web console introduced* column.

**Table 5.2. VM managemennt tasks that cannot be performed using the web console in RHEL 8.0**

| Task | Support in web console introduced | Alternative method by using CLI |
|---|---|---|
| Setting a virtual machine to start when the host boots | RHEL 8.1 | **virsh autostart** |
| Suspending a virtual machine | RHEL 8.1 | **virsh suspend** |

| Task | Support in web console introduced | Alternative method by using CLI |
|---|---|---|
| Resuming a suspended virtual machine | RHEL 8.1 | **virsh resume** |
| Creating file-system directory storage pools | RHEL 8.1 | **virsh pool-define-as** |
| Creating NFS storage pools | RHEL 8.1 | **virsh pool-define-as** |
| Creating physical disk device storage pools | RHEL 8.1 | **virsh pool-define-as** |
| Creating LVM volume group storage pools | RHEL 8.1 | **virsh pool-define-as** |
| Creating partition-based storage pools | *CURRENTLY UNAVAILABLE* | **virsh pool-define-as** |
| Creating GlusterFS-based storage pools | *CURRENTLY UNAVAILABLE* | **virsh pool-define-as** |
| Creating vHBA-based storage pools with SCSI devices | *CURRENTLY UNAVAILABLE* | **virsh pool-define-as** |
| Creating Multipath-based storage pools | *CURRENTLY UNAVAILABLE* | **virsh pool-define-as** |
| Creating RBD-based storage pools | *CURRENTLY UNAVAILABLE* | **virsh pool-define-as** |
| Creating a new storage volume | RHEL 8.1 | **virsh vol-create** |
| Adding a new virtual network | RHEL 8.1 | **virsh net-create** or **virsh net-define** |
| Deleting a virtual network | RHEL 8.1 | **virsh net-undefine** |
| Creating a bridge from a host machine's interface to a virtual machine | *CURRENTLY UNAVAILABLE* | **virsh iface-bridge** |
| Creating a snapshot | *CURRENTLY UNAVAILABLE* | **virsh snapshot-create-as** |
| Reverting to a snapshot | *CURRENTLY UNAVAILABLE* | **virsh snapshot-revert** |
| Deleting a snapshot | *CURRENTLY UNAVAILABLE* | **virsh snapshot-delete** |

| Task | Support in web console introduced | Alternative method by using CLI |
| --- | --- | --- |
| Cloning a virtual machine | RHEL 8.4 | **virt-clone** |
| Migrating a virtual machine to another host machine | RHEL 8.5 | **virsh migrate** |
| Attaching a host device to a VM | RHEL 8.5 | **virt-xml --add-device** |
| Removing a host device from a VM | RHEL 8.5 | **virt-xml --remove-device** |

### Additional resources

- Getting started with Virtual Machine Manager in RHEL 7 ( *Deprecated in RHEL 8 and later* )

# CHAPTER 6. VIEWING INFORMATION ABOUT VIRTUAL MACHINES

When you need to adjust or troubleshoot any aspect of your virtualization deployment on RHEL 8, the first step you need to perform usually is to view information about the current state and configuration of your virtual machines. To do so, you can use the command-line interface or the web console. You can also view the information in the VM's XML configuration.

## 6.1. VIEWING VIRTUAL MACHINE INFORMATION BY USING THE COMMAND-LINE INTERFACE

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 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 .

## 6.2. VIEWING VIRTUAL MACHINE INFORMATION BY USING THE WEB CONSOLE

By using the RHEL 8 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.

### 6.2.1. Viewing a virtualization overview in the web console

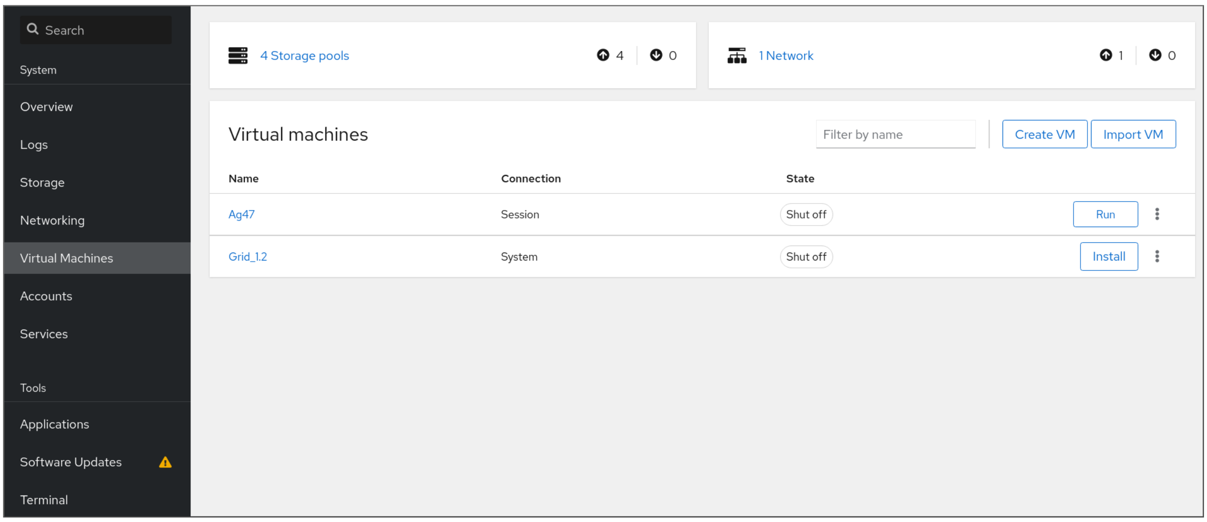
By using the web console, you can access a virtualization overview that contains summarized information about available virtual machines (VMs), storage pools, and networks.

#### 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.




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

## 6.2.2. Viewing storage pool information by using the web console

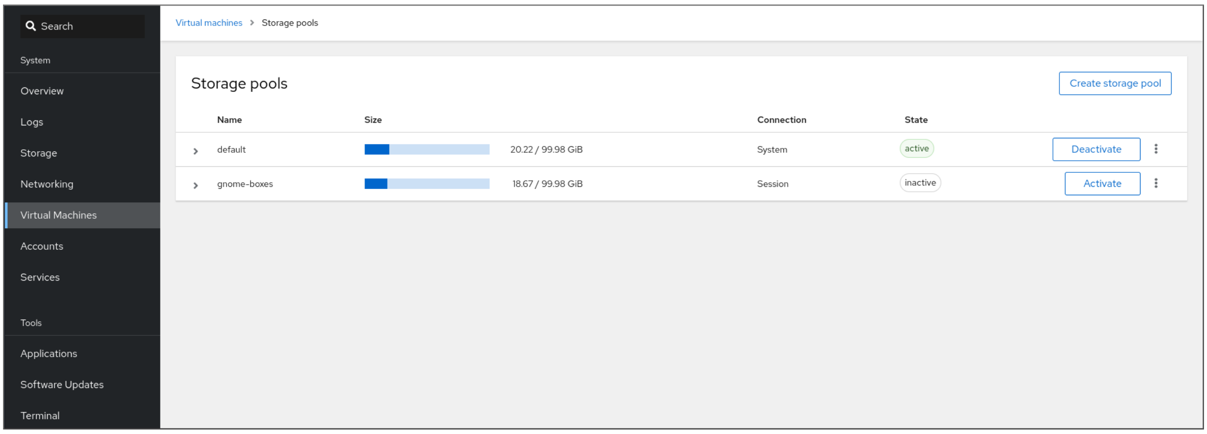
By using the web console, you can view detailed information about storage pools available on your system. Storage pools can be used to create disk images for your virtual machines.

### Prerequisites

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

### Procedure

1. Click **Storage Pools** at the top of the **Virtual Machines** interface.
   The **Storage pools** window appears, showing a list of configured storage pools.

   The information includes the following:

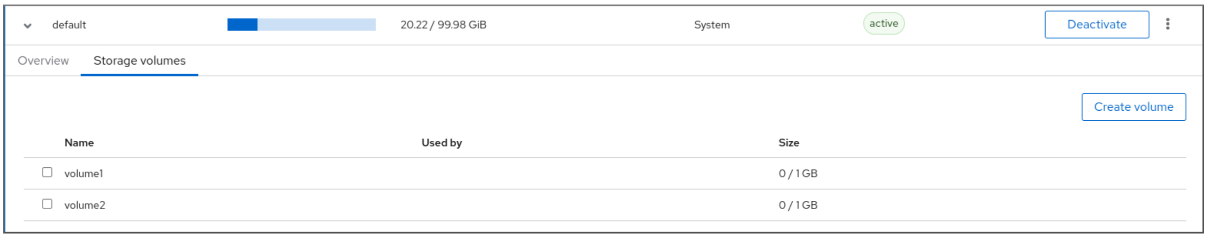
   - **Name** - The name of the storage pool.
   - **Size** - The current allocation and the total capacity of the storage pool.
   - **Connection** - The connection used to access the storage pool.
   - **State** - The state of the storage pool.

2. 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.


The information includes:

- **Target path** - The source for the types of storage pools backed by directories, such as **dir** or **netfs**.
- **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.

3. 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.




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

## 6.2.3. 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).

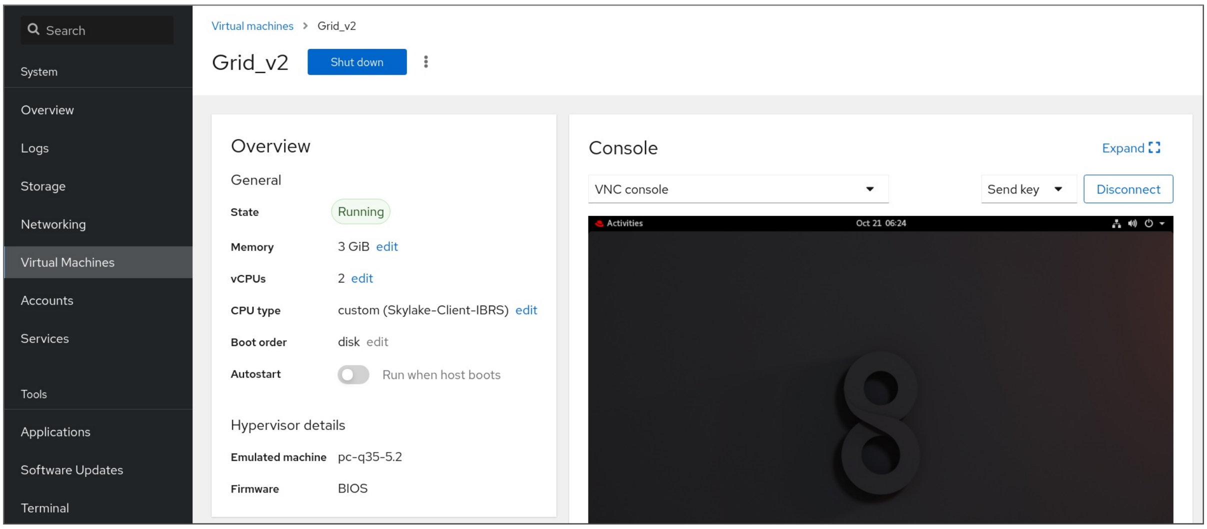
### Prerequisites

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

### Procedure

1. Click **Virtual Machines** in the web console side menu.
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.




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.
- **vCPUs** - The number of virtual CPUs configured for the VM.
- **CPU Type** - The architecture of the 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

## 6.2.4. 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).

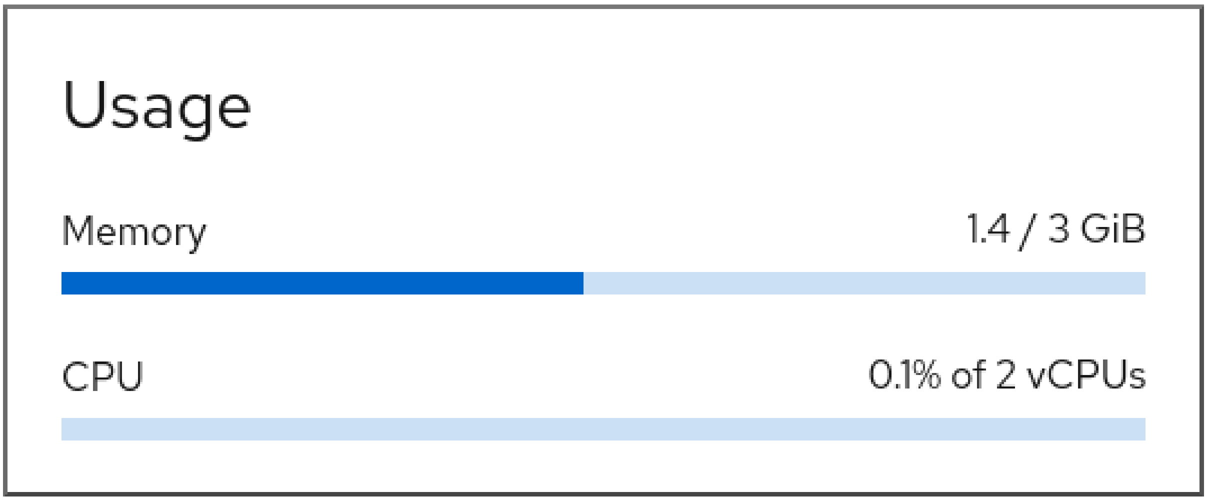
### Prerequisites

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

### Procedure

1. 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.

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




### Additional resources

- Viewing virtual machine information by using the web console

## 6.2.5. 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).

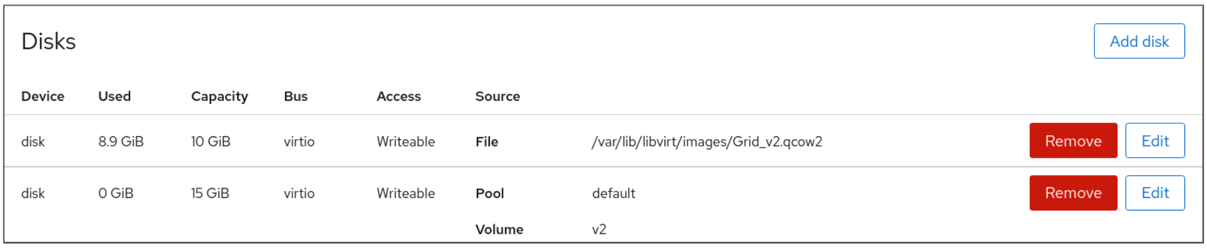
### Prerequisites

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

### Procedure

1. 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.

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




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

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

By using the RHEL 8 web console, you can view and modify the virtual network interfaces on a selected virtual machine (VM):

#### Prerequisites

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

#### Procedure

1. 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.

2. 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.

   The information includes the following:

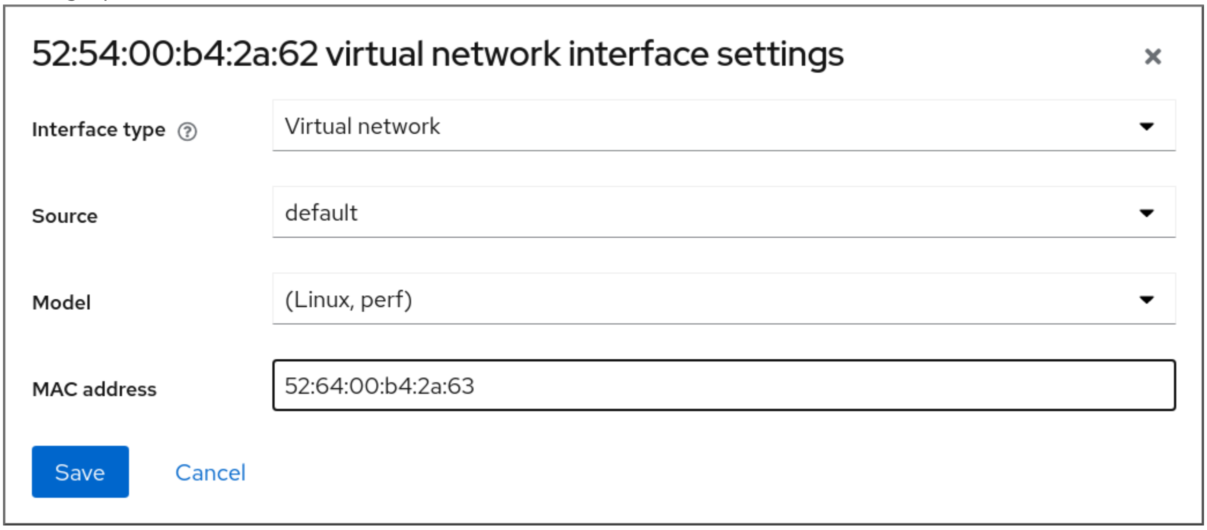
   - **Type** - The type of network interface for the VM. The types include virtual network, bridge to LAN, and direct attachment.

     > **NOTE**
     >
     > Generic Ethernet connection is not supported in RHEL 8 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.

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




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

## 6.3. 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 6.1. Sample XML configuration**

| Domain XML Section | Description |
|---|---|
| <domain type='kvm'><br><name>Testguest1</name><br><uuid>ec6fbaa1-3eb4-49da-bf61-bb02fbec4967</uuid><br><memory unit='KiB'>1048576</memory><br><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).<br><br>For information about configuring vCPUs, see Optimizing virtual machine CPU performance. |
| <os><br><type arch='x86_64' machine='pc-q35-4.1'>hvm</type><br><boot dev='hd'/><br></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.<br><br>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><br><acpi/><br><apic/><br></features> | The **acpi** and **apic** hypervisor features are disabled. |
| <cpu mode='host-model' check='partial'/> | The host CPU definitions from capabilities XML (obtainable with **virsh capabilities**) 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. |

<table>
<tr><th>Domain XML Section</th><th>Description</th></tr>
<tr><td><pre><code><clock offset='utc'>
 <timer name='rtc' tickpolicy='catchup'/>
 <timer name='pit' tickpolicy='delay'/>
 <timer name='hpet' present='no'/>
</clock></code></pre></td><td>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.</td></tr>
<tr><td><pre><code><on_poweroff>destroy</on_poweroff>
<on_reboot>restart</on_reboot>
<on_crash>destroy</on_crash></code></pre></td><td>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.</td></tr>
<tr><td><pre><code><pm>
 <suspend-to-mem enabled='no'/>
 <suspend-to-disk enabled='no'/>
</pm></code></pre></td><td>The S3 and S4 ACPI sleep states are disabled for this VM.</td></tr>
<tr><td><pre><code><devices>
 <emulator>/usr/bin/qemu-kvm</emulator>
 <disk type='file' device='disk'>
  <driver name='qemu' type='qcow2'/>
  <source file='/var/lib/libvirt/images/Testguest.qcow2'/>
  <target dev='hda' bus='ide'/>
 </disk>
 <disk type='file' device='cdrom'>
  <driver name='qemu' type='raw'/>
  <target dev='hdb' bus='ide'/>
  <readonly/>
 </disk></code></pre></td><td>The VM uses the /usr/bin/qemu-kvm binary file for emulation and it has two disk devices attached.<br><br>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 hda.<br><br>The second disk is a virtualized CD-ROM and its logical device name is set to hdb.</td></tr>
</table>

| Domain XML Section | Description |
| --- | --- |
| `<controller type='usb' index='0' model='qemu-xhci' ports='15'/>`<br>`<controller type='sata' index='0'/>`<br>`<controller type='pci' index='0' model='pcie-root'/>`<br>`<controller type='pci' index='1' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='1' port='0x10'/>`<br>`</controller>`<br>`<controller type='pci' index='2' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='2' port='0x11'/>`<br>`</controller>`<br>`<controller type='pci' index='3' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='3' port='0x12'/>`<br>`</controller>`<br>`<controller type='pci' index='4' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='4' port='0x13'/>`<br>`</controller>`<br>`<controller type='pci' index='5' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='5' port='0x14'/>`<br>`</controller>`<br>`<controller type='pci' index='6' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='6' port='0x15'/>`<br>`</controller>`<br>`<controller type='pci' index='7' model='pcie-root-port'>`<br>`<model name='pcie-root-port'/>`<br>`<target chassis='7' port='0x16'/>`<br>`</controller>`<br>`<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.<br><br>For more information about virtual devices, see Types of virtual devices. |
| `<interface type='network'>`<br>`<mac address='52:54:00:65:29:21'/>`<br>`<source network='default'/>`<br>`<model type='rtl8139'/>`<br>`</interface>` | A network interface is set up in the VM that uses the **default** virtual network and the **rtl8139** network device model.<br><br>For information about configuring the network interface, see Optimizing virtual machine network performance. |

| Domain XML Section | Description |
|---|---|
| <serial type='pty'><br><target type='isa-serial' port='0'><br><model name='isa-serial'/><br></target><br></serial><br><console type='pty'><br><target type='serial' port='0'/><br></console><br><channel type='unix'><br><target type='virtio' name='org.qemu.guest_agent.0'/><br><address type='virtio-serial' controller='0' bus='0' port='1'/><br></channel><br><channel type='spicevmc'><br><target type='virtio' name='com.redhat.spice.0'/><br><address type='virtio-serial' controller='0' bus='0' port='2'/><br></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, and the paravirtualized **SPICE** on port 2. This is set up automatically and changing these settings is not recommended.<br><br>For more information about interacting with VMs, see Interacting with virtual machines by using the web console. |
| <input type='tablet' bus='usb'><br><address type='usb' bus='0' port='1'/><br></input><br><input type='mouse' bus='ps2'/><br><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='spice' autoport='yes' listen='127.0.0.1'><br><listen type='address' address='127.0.0.1'/><br><image compression='off'/><br></graphics><br><graphics type='vnc' port='-1' autoport='yes'<br>listen='127.0.0.1'><br><listen type='address' address='127.0.0.1'/><br></graphics> | The VM uses the **VNC** and **SPICE** protocols for rendering its graphical output, and image compression is turned off. |
| <sound model='ich6'><br><address type='pci' domain='0x0000' bus='0x00'<br>slot='0x04' function='0x0'/><br></sound><br><video><br><model type='qxl' ram='65536' vram='65536'<br>vgamem='16384' heads='1' primary='yes'/><br><address type='pci' domain='0x0000' bus='0x00'<br>slot='0x02' function='0x0'/><br></video> | An **ICH6** HDA sound device is set up for the VM, and the QEMU **QXL** paravirtualized framebuffer device is set up as the video accelerator. This is set up automatically and changing these settings is not recommended. |

| Domain XML Section | Description |
|---|---|
| <redirdev bus='usb' type='spicevmc'><br><address type='usb' bus='0' port='1'/><br></redirdev><br><redirdev bus='usb' type='spicevmc'><br><address type='usb' bus='0' port='2'/><br></redirdev><br><memballoon model='virtio'><br><address type='pci' domain='0x0000' bus='0x00' slot='0x07' function='0x0'/><br></memballoon><br></devices><br></domain> | The VM has two re-directors for attaching USB devices remotely, and memory ballooning is turned on. This is set up automatically and changing these settings is not recommended. |

# CHAPTER 7. 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.

## 7.1. 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 interface (CLI). For instructions, see Saving virtual machines by using the command line interface.

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

## 7.2. SAVING A VIRTUAL MACHINE BY USING THE COMMAND LINE INTERFACE

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 interface
- Restoring a saved VM by using the web console

## 7.3. STARTING A VIRTUAL MACHINE BY USING THE COMMAND-LINE INTERFACE

You can use the command line interface (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

## 7.4. 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 8 web console. You can also configure the VM to be started automatically when the host starts.

**Prerequisites**

- 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**

### Additional resources

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

# CHAPTER 8. 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.

## 8.1. 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 interface
- Cloning a virtual machine by using the web console

## 8.2. 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 using the **virt-sysprep** utility or you can create them manually based on your requirements.

### 8.2.1. 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 **libguestfs-tools-c** package, which contains the **virt-sysprep** utility, is installed on your host:

```
# yum install libguestfs-tools-c
```

- 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
- Cloning a virtual machine by using the command-line interface

## 8.2.2. 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 network details from ifcfg scripts by editing **/etc/sysconfig/network-scripts/ifcfg-eth[x]** as follows:

i. Remove the HWADDR and Static lines:

NOTE

If the HWADDR does not match the new guest's MAC address, the **ifcfg** will be ignored.

```
DEVICE=eth[x] BOOTPROTO=none ONBOOT=yes #NETWORK=192.0.2.0 <- REMOVE #NETMASK=255.255.255.0 <- REMOVE #IPADDR=192.0.2.1 <- REMOVE #HWADDR=xx:xx:xx:xx:xx <- REMOVE #USERCTL=no <- REMOVE # Remove any other *unique or non-desired settings, such as UUID.*
```

ii. Configure DHCP but do not include HWADDR or any other unique information:

```
DEVICE=eth[x] BOOTPROTO=dhcp ONBOOT=yes
```

c. Ensure the following files also contain the same content, if they exist on your system:

- **/etc/sysconfig/networking/devices/ifcfg-eth[x]**
- **/etc/sysconfig/networking/profiles/default/ifcfg-eth[x]**

NOTE

If you had used **NetworkManager** or any special settings with the VM, ensure that any additional unique information is removed from the **ifcfg** scripts.

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.

## 8.3. CLONING A VIRTUAL MACHINE BY USING THE COMMAND-LINE INTERFACE

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-1-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
- Migrating virtual machines

## 8.4. 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

- The web console VM plug-in is installed on your system.
- Ensure that the VM you want to clone is shut down.

### Procedure

1. 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.

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


3. **Optional:** Enter a new name for the VM clone.

4. 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 9. 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.

## 9.1. HOW MIGRATING VIRTUAL MACHINES WORKS

The essential part of virtual machine (VM) migration is copying the XML configuration of a VM to a different host machine. If the migrated VM is not shut down, the migration also transfers the state of the VM's memory and any virtualized devices to a destination host machine. For the VM to remain functional on the destination host, the VM's disk images must remain available to it.

By default, the migrated VM is transient on the destination host, and remains defined also on the source host.

You can migrate a running VM by using *live* or *non-live* migrations. To migrate a shut-off VM, you must use an *offline* migration. For details, see the following table.

**Table 9.1. 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, VMs that modify memory pages faster than KVM can transfer them, such as VMs under heavy I/O load, cannot be live-migrated, and *non-live migration* must be used instead. | The VM's disk images must be located on a shared network, accessible both to the source host and the destination host. |
| **Non-live migration** | Suspends the VM, copies its configuration and its memory to the destination host, and resumes the VM. | Creates downtime for the VM, but is generally more reliable than live migration. Recommended for VMs under heavy memory load. | The VM's disk images must be located on a shared network, accessible both to the source host and the destination host. |
| **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 available on a shared network, and can be copied or moved manually to the destination host instead. |

You can also combine *live migration* and *non-live migration*. This is recommended for example when live-migrating a VM that uses very many vCPUs or a large amount of memory, which prevents the migration from completing. In such a scenario, you can suspend the source VM. This prevents additional dirty memory pages from being generated, and thus makes it significantly more likely for the migration to complete. Based on guest workload and the number of static pages during migration, such a *hybrid* migration might cause significantly less downtime than a non-live migration.

**Additional resources**

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

## 9.2. 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.

## 9.3. LIMITATIONS FOR MIGRATING VIRTUAL MACHINES

Before migrating virtual machines (VMs) in RHEL 8, ensure you are aware of the migration's limitations.

- Live storage migration cannot be performed on RHEL 8, but you can migrate storage while the VM is powered down. Note that live storage migration is available on Red Hat Virtualization.
- Migrating VMs from or to a session connection of **libvirt** is unreliable and therefore not recommended.
- 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
  - Mediated devices, such as vGPUs
- 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.
- The emulated 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.
- Firmware settings
- Microcode version
- BIOS version
- BIOS settings
- QEMU version
- Kernel version

- Live migrating a VM that uses more than 1 TB of memory might in some cases be unreliable. For instructions on how to prevent or fix this problem, see Live migration of a VM takes a long time without completing.

## 9.4. 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

### 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, restart it.

```
# virsh reboot VM-name
```

**Next steps**

- Sharing virtual machine disk images with other hosts
- Migrating a virtual machine by using the command-line interface
- Live-migrating a virtual machine by using the web console

## 9.5. SHARING VIRTUAL MACHINE DISK IMAGES WITH OTHER HOSTS

To perform a live migration of a virtual machine (VM) between supported KVM hosts, shared VM storage is required. 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 is installed and enabled on the source and destination hosts. See
- Deploying an NFS server.

### 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 source host that will hold the disk image and 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. 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

## 9.6. MIGRATING A VIRTUAL MACHINE BY USING THE COMMAND-LINE INTERFACE

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. The following procedure provides instructions and examples for various scenarios of such migrations.

### Prerequisites

- The source host and the destination host both use the KVM hypervisor.
- The source host and the destination host are able to reach each other over the network. Use the **ping** utility to verify this.
- Ensure the following ports are open on the destination host.
  - Port 22 is needed for connecting to the destination host by using SSH.
  - Port 16509 is needed for connecting to the destination host by using TLS.
  - Port 16514 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.
- 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.
- 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 .
- The disk images of VMs that will be migrated are located on a separate networked location accessible to both the source host and the destination host. This is optional for offline migration, but required for migrating a running VM.
  For instructions to set up such shared VM storage, see Sharing virtual machine disk images with other hosts.
- 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.

- 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 operate after migration.

> **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.

- Ensure that the **libvirtd** service is enabled and running.

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

### Procedure

1. Use the **virsh migrate** command with options appropriate for your migration requirements.

   a. The following command migrates the **example-VM-1** 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 --persistent --live example-VM-1 qemu+ssh://example-destination/system
   ```

   b. The following commands enable you to make manual adjustments to the configuration of the **example-VM-2** VM running on your local host, and then migrate the VM to the **example-destination** host. The migrated VM will automatically use the updated configuration.

   ```
   # virsh dumpxml --migratable example-VM-2 > example-VM-2.xml
   # vi example-VM-2.xml
   # virsh migrate --live --persistent --xml example-VM-2.xml example-VM-2
   qemu+ssh://example-destination/system
   ```

   This procedure can be useful for example when the destination host needs to use a different path to access the shared VM storage or when configuring a feature specific to the destination host.

   c. The following command suspends the **example-VM-3** VM from the **example-source** host, migrates it to the **example-destination** host, and instructs it to use the adjusted XML configuration, provided by the **example-VM-3-alt.xml** file. When the migration is completed, **libvirt** resumes the VM on the destination host.

```
# virsh migrate example-VM-3 qemu+ssh://example-source/system qemu+ssh://example-destination/system --xml example-VM-3-alt.xml
```

After the migration, the VM is in the shut off state on the source host, and the migrated copy is deleted after it is shut down.

d. The following deletes the shut-down **example-VM-4** VM from the **example-source** host, and moves its configuration to the **example-destination** host.

```
# virsh migrate --offline --persistent --undefinesource example-VM-4
qemu+ssh://example-source/system qemu+ssh://example-destination/system
```

Note that this type of migration does not require moving the VM's disk image to shared storage. However, for the VM to be usable on the destination host, you also need to migrate the VM's disk image. For example:

```
# scp root@example-source:/var/lib/libvirt/images/example-VM-4.qcow2 root@example-destination:/var/lib/libvirt/images/example-VM-4.qcow2
```

2. Wait for the migration to complete. The process may 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.

### Verification

- On the destination host, list the available VMs to verify if the VM has been migrated:

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

If the migration is still running, this command will list the VM state as **paused**.

### Troubleshooting

- In some cases, the target host will not be compatible with certain values of the migrated VM's XML configuration, such as the network name or CPU type. As a result, the VM will fail to boot on the target host. To fix these problems, you can update the problematic values by using the **virsh edit** command. After updating the values, you must restart the VM for the changes to be applied.

- If a live migration is taking a long time to complete, this may be because the VM is under heavy load and too many memory pages are changing for live migration to be possible. To fix this problem, change the migration to a non-live one by suspending the VM.

```
# virsh suspend example-VM-1
```

### Additional resources

- **virsh migrate --help** command
- **virsh (1)** man page

## 9.7. LIVE MIGRATING A VIRTUAL MACHINE BY USING THE WEB CONSOLE

If you wish 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.

> **WARNING**
>
> For tasks that modify memory pages faster than KVM can transfer them, such as heavy I/O load tasks, it is recommended that you do not live migrate the VM.

### Prerequisites

- The web console VM plug-in is installed on your system.
- The source and destination hosts are running.
- Ensure the following ports are open on the destination host.
  - Port 22 is needed for connecting to the destination host by using SSH.
  - Port 16509 is needed for connecting to the destination host by using TLS.
  - Port 16514 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.
- 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.
- The VM's disk images are located on a shared storage that is accessible to the source host as well as the destination host.
- 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 in your command-line interface:
  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
```

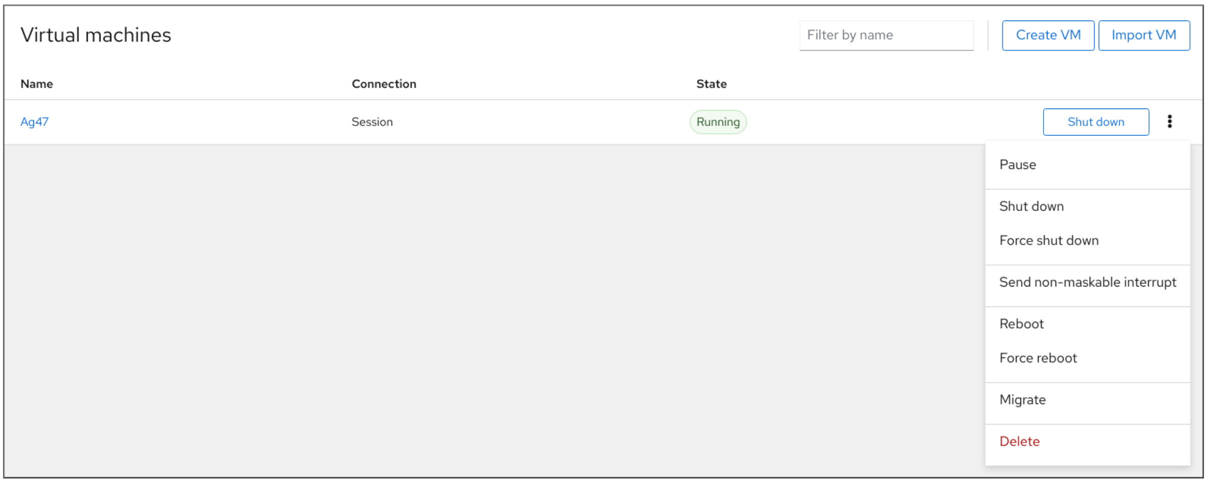
In this example, the VM is generating 2 MB of dirty memory pages per second. Attempting to live-migrate such a VM on a network with a bandwidth of 2 MB/s or less will cause the live migration not to progress if you do not pause the VM or lower its workload.

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.

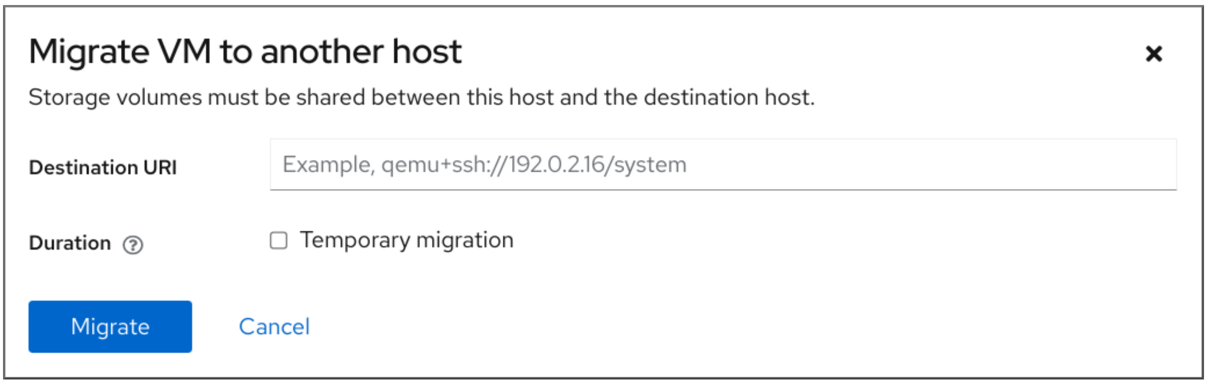
> **NOTE**
>
> The value of the **calc_period** option might differ based on the workload and dirty page rate. You can experiment with several **calc_period** values to determine the most suitable period that aligns with the dirty page rate in your environment.

### 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.




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



3. Enter the URI of the destination host.
4. Configure the duration of the migration:
    - **Permanent** - Do not check the box if you wish 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.

## 9.8. TROUBLESHOOTING VIRTUAL MACHINE MIGRATIONS

If you are facing one of the following problems when migrating virtual machines (VMs), see the provided instructions to fix or avoid the issue.

### 9.8.1. Live migration of a VM takes a long time without completing

#### Cause

In some cases, migrating a running VM might cause the the VM to generate *dirty memory pages* faster than they can be migrated. When this occurs, the migration cannot complete successfully.

The following scenarios frequently cause this problem:

- Live migrating a VM under a heavy load
- Live migrating a VM that uses a large amount of memory, such as 1 TB or more

> **IMPORTANT**
>
> Red Hat has successfully tested live migration of VMs with up to 6 TB of memory. However, for live migration scenarios that involve VMs with more than 1 TB of memory, customers should reach out to Red Hat technical support.

#### Diagnosis

If your VM live migration is taking longer than expected, use the **virsh domjobinfo** command to obtain the memory page data for the VM:

```
# virsh domjobinfo vm-name

Job type:         Unbounded
Operation:        Outgoing migration
```

```
Time elapsed:     168286974    ms
Data processed:   26.106 TiB
Data remaining:   34.383 MiB
Data total:       10.586 TiB
Memory processed: 26.106 TiB
Memory remaining: 34.383 MiB
Memory total:     10.586 TiB
Memory bandwidth: 29.056 MiB/s
Dirty rate: 17225 pages/s
Page size: 4096 bytes
```

In this output, the multiplication of **Dirty rate** and **Page size** is greater than **Memory bandwidth**. This means that the VM is generating dirty memory pages faster than the network can migrate them. As a consequence, the state of the VM on the destination host cannot converge with the state of the VM on the source host, which prevents the migration from completing.

### Fix

To improve the chances that a stalled live migration finishes successfully, you can do any of the following:

- Reduce the workload of the VM, especially memory updates.
    - To do this, stop or cancel non-essential processes in the guest operating system of the source VM.
- Increase the downtime allowed for the live migration:
    a. Display the current maximum downtime at the end of a live migration for the VM that is being migrated:

    ```
    # virsh migrate-getmaxdowntime vm-name
    ```

    b. Set a higher maximum downtime:

    ```
    # virsh migrate-setmaxdowntime vm-name downtime-in-miliseconds
    ```

    The higher you set the maximum downtime, the more likely it will be for the migration to complete.
- Switch the live migration to *post-copy* mode.

    ```
    # virsh migrate-start-postcopy vm-name
    ```

    - This ensures that the memory pages of the VM can converge on the destination host, and that the migration can complete.
    However, when post-copy mode is active, the VM might slow down significantly, due to remote page requests from the destination host to the source host. In addition, if the network connection between the source host and the destination host stops working during post-copy migration, some of the VM processes may halt due to missing memory pages.

        Therefore, do not use post-copy migration if the VM availability is critical or if the migration network is unstable.

- If your workload allows it, suspend the VM and let the migration finish as a *non-live* migration. This increases the downtime of the VM, but in most cases ensures that the migration completes successfully.

**Prevention**

The probability of successfully completing a live migration of a VM depends on the following:

- The workload of the VM during the migration
  - Before starting the migration, stop or cancel non-essential processes in the guest operating system of the VM.
- The network bandwidth that the host can use for migration
  - For optimal results of a live migration, the bandwidth of the network used for the migration must be significantly higher than the dirty page generation of the VM. For instructions on obtaining the VM dirty page generation rate, see the Prerequisites in Migrating a virtual machine by using the command-line interface.
  - Both the source host and the destination host must have a dedicated network interface controller (NIC) for the migration. For live migrating a VM with more than 1 TB of memory, Red Hat recommends a NIC with the speed of 25 Gb/s or more.
  - You can also specify the network bandwidth assigned to the live migration by using the **--bandwidth** option when initiating the migration. For migrating very large VMs, assign as much bandwidth as viable for your deployment.
- The mode of live migration
  - The default *pre-copy* migration mode copies memory pages repeatedly if they become dirty.
  - *Post-copy* migration copies memory pages only once.
    To enable your live migration to switch to post-copy mode if the migration stalls, use the **--postcopy** option with **virsh migrate** when starting the migration.
- The downtime specified for the deployment
  - You can adjust this during the migration by using **virsh migrate-setmaxdowntime** as described previously.

## 9.9. 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 9.2. Live migration compatibility**

| Migration method | Release type | Example | Support status |
|---|---|---|---|
| Forward | Major release | 7.6+ → 8.1 | On supported RHEL 7 systems: machine types **i440fx** and **q35** |

| Migration method | Release type | Example | Support status |
| --- | --- | --- | --- |
| Backward | Major release | 8.1 → 7.6+ | On supported RHEL 8 systems: machine types **i440fx** and **q35** |
| Forward | Minor release | 8.0.1+ → 8.1+ | On supported RHEL 7 systems: machine types **i440fx** and **q35** on RHEL 7.6.0 and later.<br><br>On supported RHEL 8 systems: machine type **q35**. |
| Backward | Minor release | 8.1 → 8.0.1 | On supported RHEL 7 systems. Fully supported for machine types **i440fx** and **q35**.<br><br>On supported RHEL 8 systems: machine type **q35**. |

#### Additional resources

- Red Hat Enterprise Linux life cycle

## 9.10. ADDITIONAL RESOURCES

- Converting virtual machines from other hypervisors to KVM with **virt-v2v** in RHEL 7 and RHEL 8

# CHAPTER 10. 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.

## 10.1. 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 interface (CLI). However, to manage virtual storage devices and NICs, you can also use the RHEL 8 web console.

### Performance or flexibility

For some types of devices, RHEL 8 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.

### Additional resources

- Managing storage for virtual machines
- Using the web console for managing virtual machine network interfaces
- Managing NVIDIA vGPU devices

## 10.2. TYPES OF VIRTUAL DEVICES

Virtualization in RHEL 8 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 or QXL 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 8 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**).
- The paravirtualized graphics card (**QXL**).

#### 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.

## 10.3. 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 interface (CLI).

You can use the CLI to:

- Attach devices
- Modify devices
- Remove devices

### 10.3.1. 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 interface (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. This is also referred to as **memory hot plug**.

WARNING

Removing a memory device from a VM, also known as **memory hot unplug**, is not supported in RHEL 8, and Red Hat highly discourages its use.

**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

## 10.3.2. 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 interface (CLI). Some devices attached to your VM, such as disks and NICs, can also be modified using the RHEL 8 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

## 10.3.3. 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 interface (CLI). Some devices, such as disks or NICs, can also be removed from VMs using the RHEL 8 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

## 10.4. 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 8 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

### 10.4.1. Viewing devices attached to virtual machines by using the web console

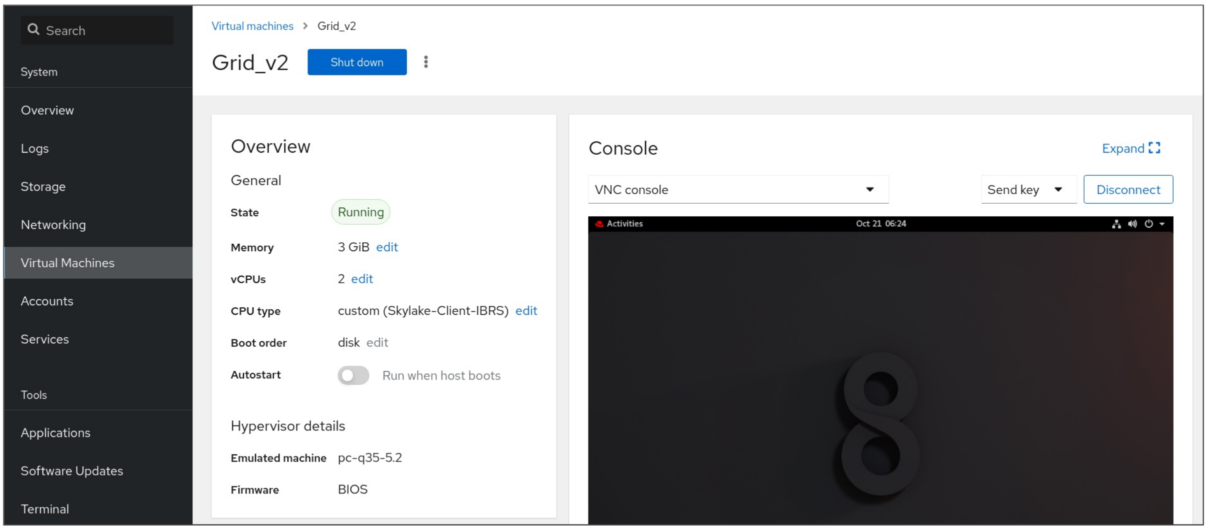
Before adding or modifying the devices attached to your virtual machine (VM), you may want to view the devices that are already attached to your VM. The following procedure provides instructions for viewing such devices by using the web console.

**Prerequisites**

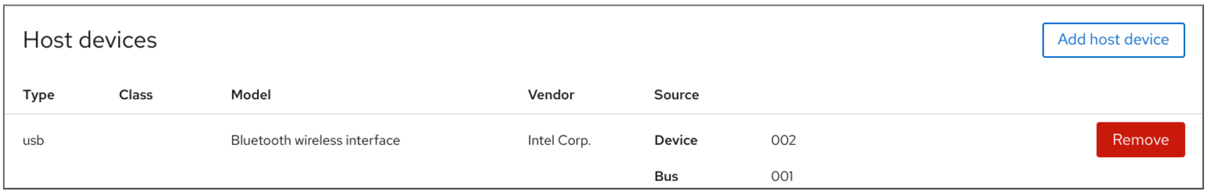
- The web console VM plug-in is installed on your system.

**Procedure**

1. In the **Virtual Machines** interface, click the VM whose information you want to see.
   A new page opens with detailed information about the VM.




2. Scroll to the **Host devices** section.




### Additional resources

- Managing virtual devices

## 10.4.2. 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 8 Known Issues.

### Prerequisites

- 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
```

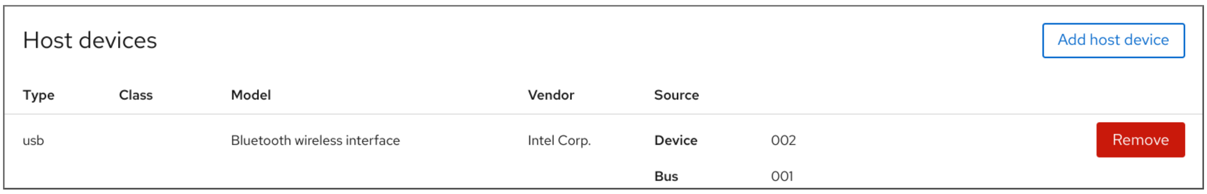
- Back up important data from the VM.
- **Optional:** Back up the XML configuration of your VM. For example, to back up the **example-VM-1** VM:

```
# virsh dumpxml example-VM-1 > example-VM-1.xml
```

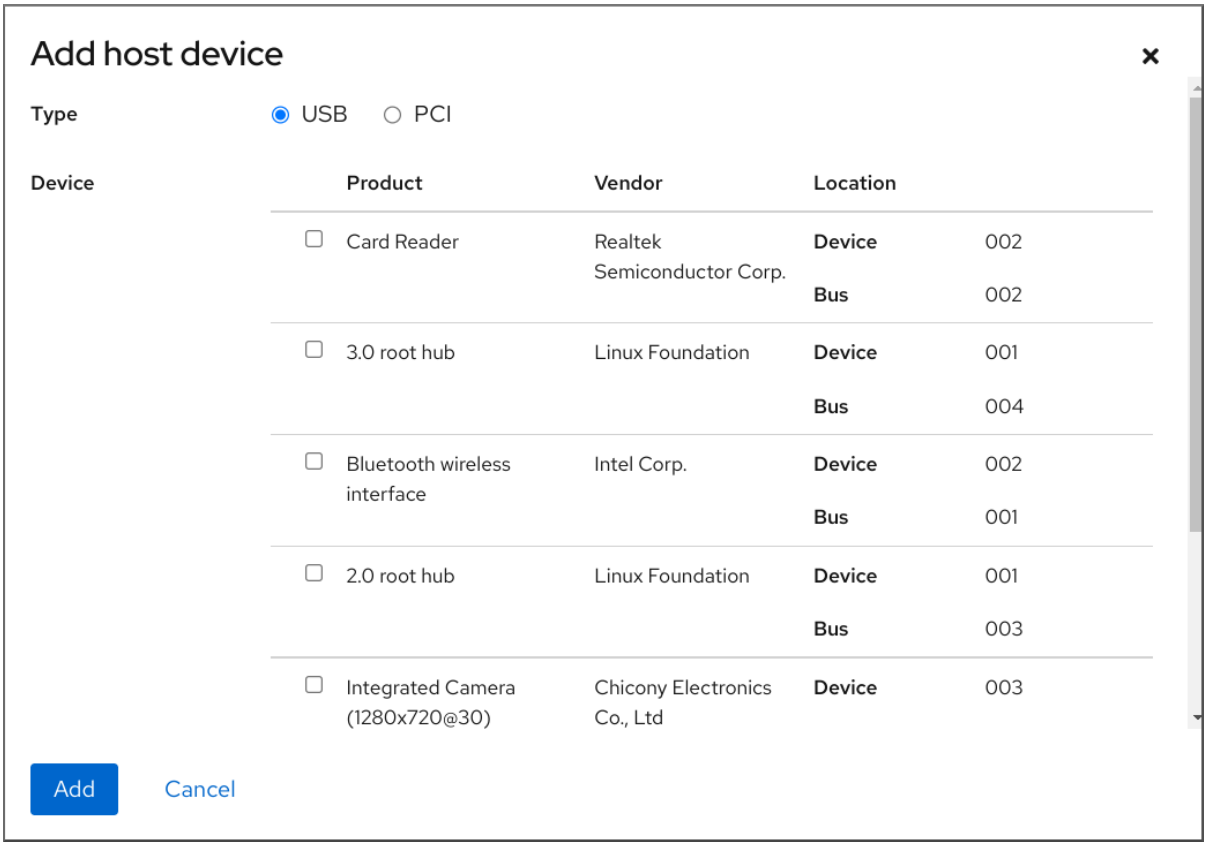
- The web console VM plug-in is installed on your system .

### Procedure

1. 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.
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.




3. Click **Add host device**.
   The **Add host device** dialog appears.




4. Select the device you wish to attach to the VM.

5. 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.

## 10.4.3. 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 8 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>
> ```

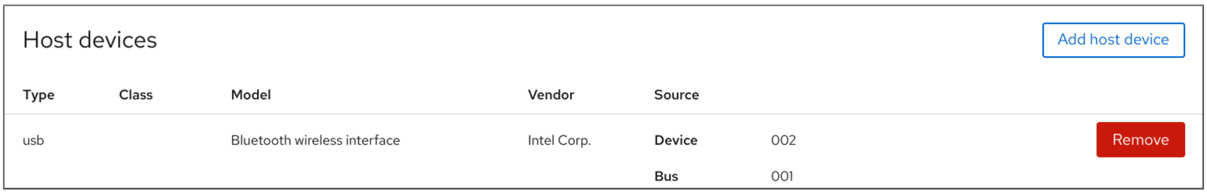
### Prerequisites

- 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:

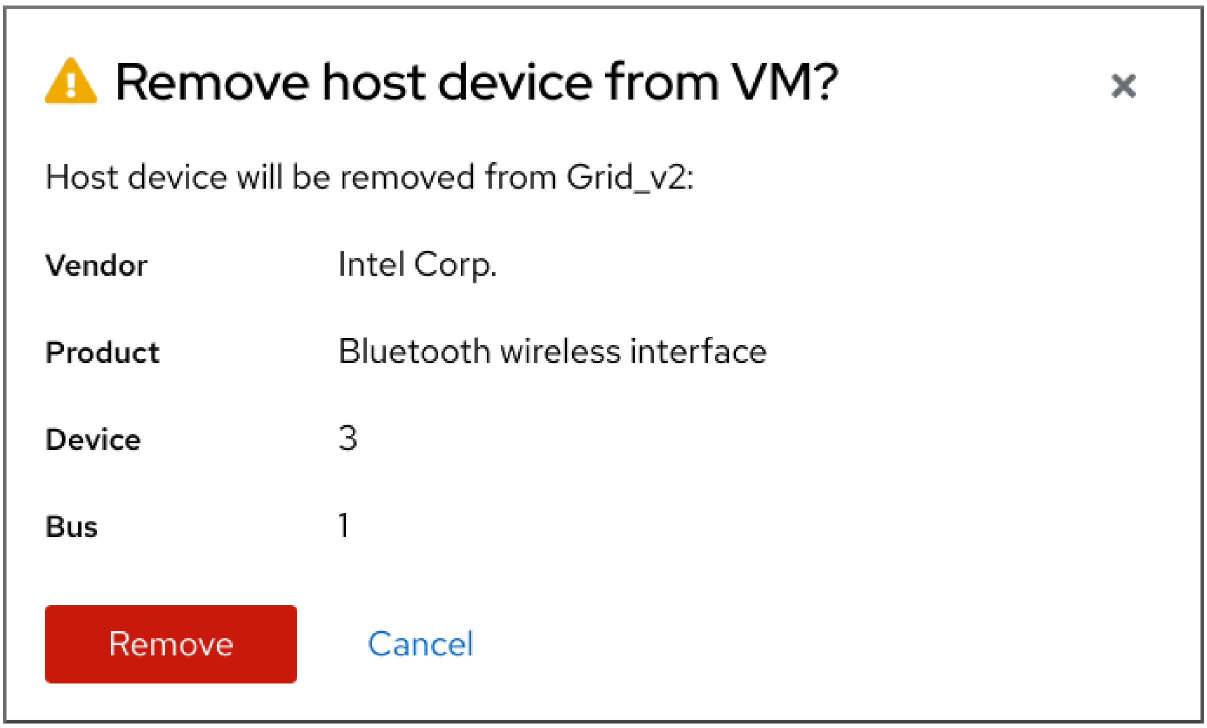
```
# virsh dumpxml testguest1 > testguest1.xml
# cat testguest1.xml
<domain type='kvm' xmlns:qemu='http://libvirt.org/schemas/domain/qemu/1.0'>
  <name>testguest1</name>
  <uuid>ede29304-fe0c-4ca4-abcd-d246481acd18</uuid>
  [...]
</domain>
```

### 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.




3. Click the **Remove** button next to the device you want to remove from the VM.
   A remove device confirmation dialog appears.



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
  ```

## 10.5. 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.

The following sections provide information about using the command line to:

- Attach a USB device to a VM
- Remove a USB device from a VM

### 10.5.1. 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

- The **virt-xml (1)** man page
- Attaching devices to virtual machines

### 10.5.2. 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

- The **virt-xml (1)** man page
- Attaching devices to virtual machines

## 10.5.3. Attaching smart card readers to virtual machines

If you have a smart card reader attached to a host, you can also make it available to virtual machines (VMs) on that host. Libvirt provides a specialized virtual device that presents a smart card interface to the guest VM. It is recommended you only use the **spicevmc** device type, which utilizes the SPICE remote display protocol to tunnel authentication requests to the host.

Although it is possible to use standard device passthrough with smart card readers, this method does not make the device available on both the host and guest system. As a consequence, you could lock the host system when you attach the smart card reader to the VM.

> **IMPORTANT**
>
> The SPICE remote display protocol has become deprecated in RHEL 8. Since the only recommended way to attach smart card readers to VMs depends on the SPICE protocol, the usage of smart cards in guest VMs is also deprecated in RHEL 8.
>
> In a future major version of RHEL, the functionality of attaching smart card readers to VMs will only be supported by third party remote visualization solutions.

### Prerequisites

- Ensure the smart card reader you want to pass through to the VM is attached to the host.
- Ensure the smart card reader type is supported in RHEL 8 .

### Procedure

- Create and attach a virtual smart card reader device to a VM. For example, to attach a smart card reader to the **testguest** VM:

  ```
  # virt-xml testguest --add-device --smartcard mode=passthrough,type=spicevmc
  Domain 'testguest' defined successfully.
  Changes will take effect after the domain is fully powered off.
  ```

  > **NOTE**
  >
  > To attach a virtual smart card reader device to a running VM, add the **--update** argument to the previous command.

#### Verification

1. View the XML configuration of the VM.

```
# virsh dumpxml testguest
```

2. Ensure the XML configuration contains the following smart card device definition.

```
<smartcard mode='passthrough' type='spicevmc'/>
```

## 10.6. 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.

The following sections provide information about using the command line to:

- Attach a drive and an ISO image to a VM
- Attach a CD-ROM to a running VM
- Replace an ISO image in a virtual optical drive
- Remove an ISO image from a virtual optical drive
- Remove a drive from the VM
- Remove a CD-ROM from a running VM

### 10.6.1. 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

### 10.6.2. 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**, **Remove**, or **Edit** disks.
6. Click the **Insert** option for the **cdrom** device.


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.

### 10.6.3. 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

## 10.6.4. 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

## 10.6.5. 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

## 10.6.6. Removing a CD-ROM from a running virtual machine by using the web console

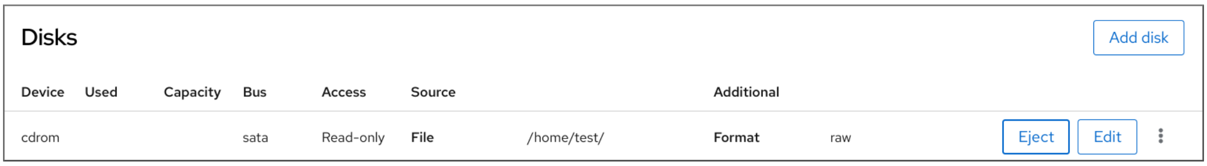
You can use the web console to eject a CD-ROM device from a running virtual machine (VM).

### 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**, **Remove**, or **Edit** disks.




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.

# 10.7. 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.

## 10.7.1. 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

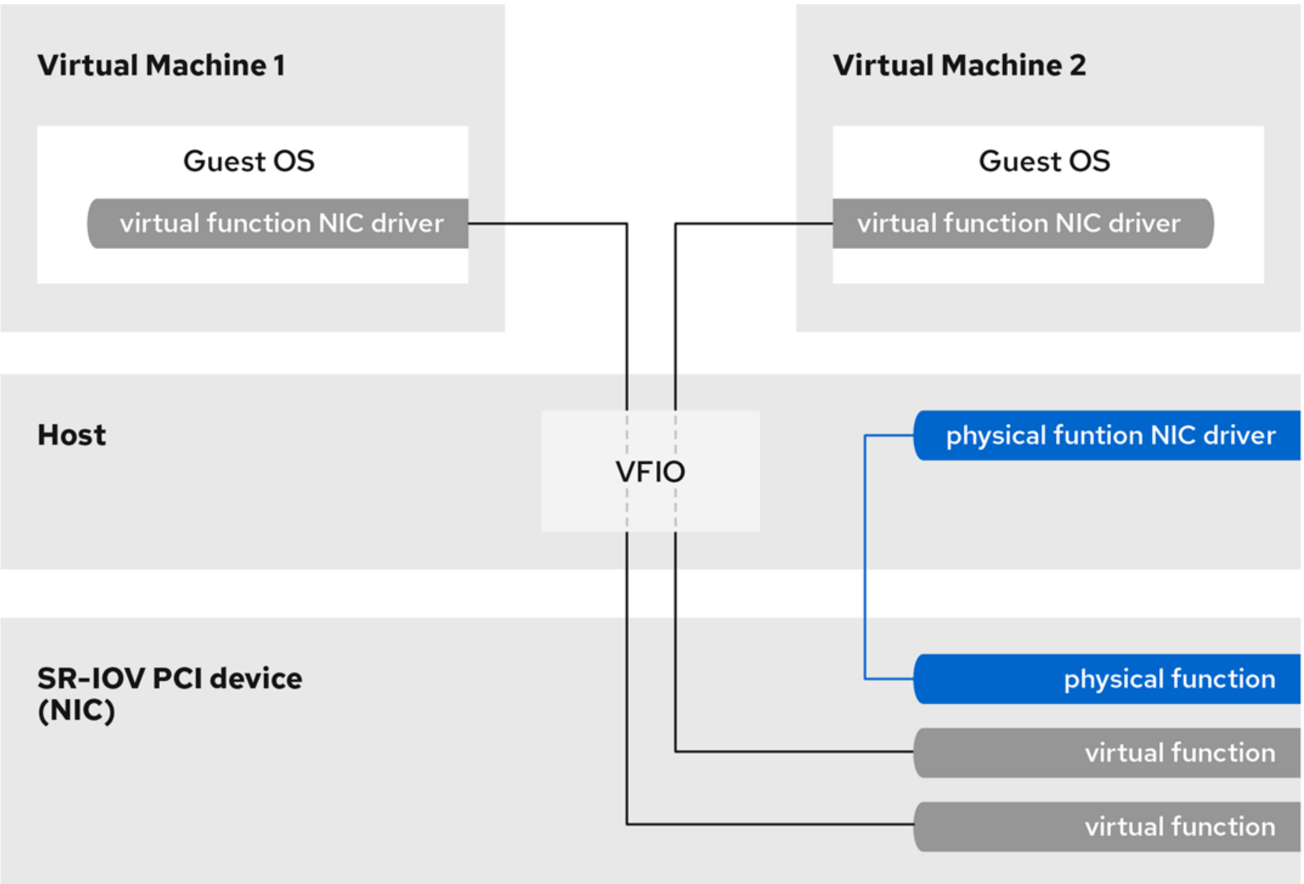
The SR-IOV functionality is possible thanks to the introduction of the following PCIe functions:

- **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 10.1. 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 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

### 10.7.2. Attaching SR-IOV networking devices to virtual machines

To attach an SR-IOV networking device to a virtual machine (VM) on an Intel or AMD host, 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.

**Procedure**

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 testguest1 hostdev 0000:82:10.0 --managed --live --config
```

### Verification

- If the procedure is successful, the guest operating system detects a new network interface card.

## 10.7.3. 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 8.

### Networking devices

- Intel 82599ES 10 Gigabit Ethernet Controller - uses the **ixgbe** driver
- Intel Ethernet Controller XL710 Series - uses the **i40e** driver
- Mellanox ConnectX-5 Ethernet Adapter Cards - use the **mlx5_core** 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
- MT2892 Family [ConnectX-6 Dx] - uses the **mlx5_core** driver

#### Storage devices

- Non-Volatile memory controller: Samsung Electronics Co Ltd NVMe SSD Controller 172Xa/172Xb (rev 01)
- Non-Volatile memory controller: Toshiba Corporation Cx5 NVMe SSD Controller (rev 01)

## 10.8. 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.

  ```
  # yum 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

## 10.9. 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 web console VM plug-in on your system. For more information, see Section 5.2, “Setting up the web console to manage virtual machines”.

### Procedure

1. In the command line interface, install the watchdog service.
   # **yum install watchdog**

2. Shut down the VM.

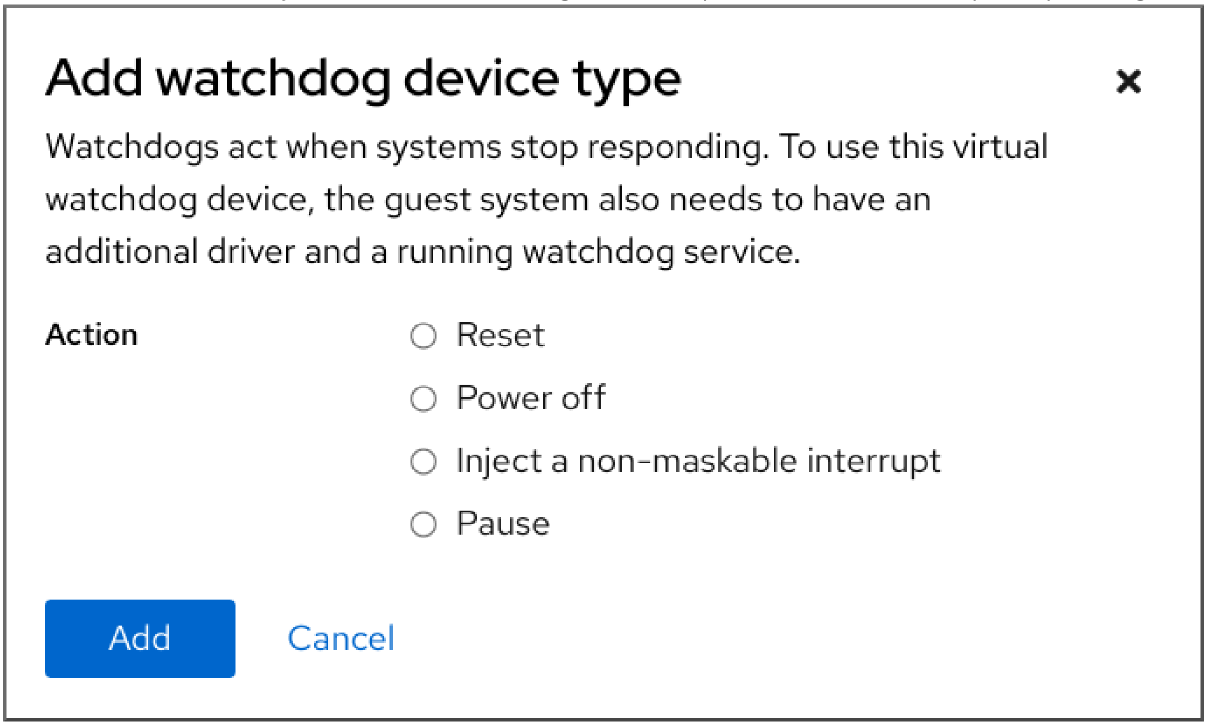
3. Add the watchdog service to the VM.
   # **virt-xml *vmname* --add-device --watchdog action=reset --update**

4. Run the VM.

5. Open the web console and in the **Virtual Machines** interface of the web console, click on the VM to which you want to add the watchdog device.

6. Click **add** next to the **Watchdog** field in the Overview pane.
   The **Add watchdog device type** dialog appears.

7. Select the action that you want the watchdog device to perform if the VM stops responding.




8. Click **Add**.

**Verification**

- The action you selected is visible next to the **Watchdog** field in the Overview pane.

## 10.10. ATTACHING PCI DEVICES TO VIRTUAL MACHINES ON IBM Z

By using the **vfio-pci** device driver, you can assign PCI devices in pass-through mode to your virtual machines (VMs) on IBM Z hosts. This for example makes it possible for the VM to use NVMe flash disks for handling databases.

**Prerequisites**

- You have a host system with the IBM Z hardware architecture.

- You have a target VM of Linux operating system.

- 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_pci**

- **vfio_pci_core**
- **vfio_iommu_type1**

## Procedure

1. Obtain the PCI address identifier of the device that you want to use.

```
# lspci -nkD

0000:00:00.0 0000: 1014:04ed
 Kernel driver in use: ism
 Kernel modules: ism
0001:00:00.0 0000: 1014:04ed
 Kernel driver in use: ism
 Kernel modules: ism
0002:00:00.0 0200: 15b3:1016
 Subsystem: 15b3:0062
 Kernel driver in use: mlx5_core
 Kernel modules: mlx5_core
0003:00:00.0 0200: 15b3:1016
 Subsystem: 15b3:0062
 Kernel driver in use: mlx5_core
 Kernel modules: mlx5_core
```

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. For example, if the device address is **0003:00:00.0**, use the following configuration:

```
<hostdev mode="subsystem" type="pci" managed="yes">
  <driver name="vfio"/>
   <source>
    <address domain="0x0003" bus="0x00" slot="0x00" function="0x0"/>
   </source>
   <address type="pci"/>
</hostdev>
```

4. **Optional:** To modify how the guest operating system will detect the PCI device, you can also 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="0x0003" bus="0x00" slot="0x00" function="0x0"/>
   </source>
   <address type="pci">
```

```
    <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 the device address is **0003:00:00.0**, use the following command:

```
# lspci -nkD | grep 0003:00:00.0

0003:00:00.0 8086:9a09 (rev 01)
```

# CHAPTER 11. 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.

## 11.1. 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

### 11.1.1. 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.

Furthermore, 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 pool storage types

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 Management (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.

### 11.1.2. 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
```

### 11.1.3. 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.

### 11.1.4. 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**.

### 11.1.5. 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
- GlusterFS 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

## 11.2. 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 GlusterFS-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

### 11.2.1. 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

### 11.2.2. 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
```

### 11.2.3. 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 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
```

### 11.2.4. 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
```

### 11.2.5. Creating GlusterFS-based storage pools by using the CLI

GlusterFS is a user-space file system that uses the File System in Userspace (FUSE) software interface. If you want to have a storage pool on a Gluster server, you can use the **virsh** utility to create GlusterFS-based storage pools.

#### Prerequisites

- Before you can create GlusterFS-based storage pool on a host, prepare a Gluster.
    a. Obtain the IP address of the Gluster server by listing its status with the following command:

    ```
    # gluster volume status
    Status of volume: gluster-vol1
    Gluster process                           Port Online Pid
    ------------------------------------------------------------
    Brick 222.111.222.111:/gluster-vol1       49155   Y    18634

    Task Status of Volume gluster-vol1
    ------------------------------------------------------------
    There are no active volume tasks
    ```

    b. If not installed, install the **glusterfs-fuse** package.

    c. If not enabled, enable the **virt_use_fusefs** boolean. Check that it is enabled.

    ```
    # setsebool virt_use_fusefs on
    # getsebool virt_use_fusefs
    virt_use_fusefs --> on
    ```

- Ensure your hypervisor supports GlusterFS-based storage pools:

```
# virsh pool-capabilities | grep "'gluster' supported='yes'"
```

If the command displays any output, GlusterFS-based pools are supported.

**Procedure**

1. **Create a storage pool**
   Use the **virsh pool-define-as** command to define and create a GlusterFS-based storage pool. For example, to create a storage pool named **guest_images_glusterfs** that uses a Gluster server named **gluster-vol1** with IP **111.222.111.222**, and is mounted on the root directory of the Gluster server:

```
# virsh pool-define-as --name guest_images_glusterfs --type gluster --source-host
111.222.111.222 --source-name gluster-vol1 --source-path /
Pool guest_images_glusterfs 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 GlusterFS-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_glusterfs inactive   no
```

3. **Start the storage pool**
   Use the **virsh pool-start** command to mount the storage pool.

```
# virsh pool-start guest_images_glusterfs
 Pool guest_images_glusterfs 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_glusterfs
 Pool guest_images_glusterfs 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_glusterfs
 Name:           guest_images_glusterfs
 UUID:          c7466869-e82a-a66c-2187-dc9d6f0877d0
 State:         running
 Persistent:     yes
 Autostart:     yes
 Capacity:      458.39 GB
 Allocation:    197.91 MB
 Available:     458.20 GB
```

### 11.2.6. 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
```

## 11.2.7. 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 the *Red Hat Enterprise Linux Logical Volume Manager Administration Guide*.

- 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
```

## 11.2.8. 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
```

## 11.2.9. 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
```

### 11.2.10. 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
```

## 11.3. 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.
  - Create SCSI-based storage pools with vHBA devices.
- Remove storage pools.
- Deactivate storage pools.

### 11.3.1. Viewing storage pool information by using the web console

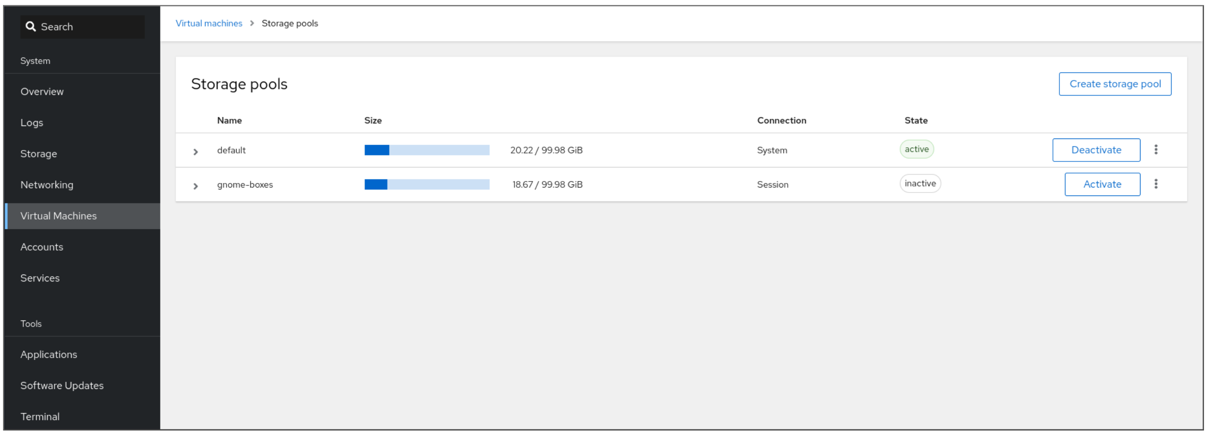
By using the web console, you can view detailed information about storage pools available on your system. Storage pools can be used to create disk images for your virtual machines.

#### Prerequisites

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

#### Procedure

1. Click **Storage Pools** at the top of the **Virtual Machines** interface.
   The **Storage pools** window appears, showing a list of configured storage pools.




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.

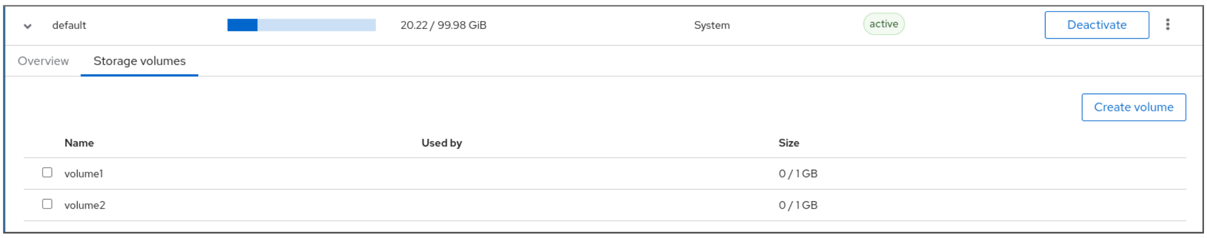
2. Click the arrow next to the storage pool whose information you want to see.
   The row expands to reveal the Overview pane with detailed information about the selected storage pool.

   The information includes:

   - **Target path** - The source for the types of storage pools backed by directories, such as **dir** or **netfs**.
   - **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.

3. 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.

   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

## 11.3.2. Creating directory-based storage pools by using the web console

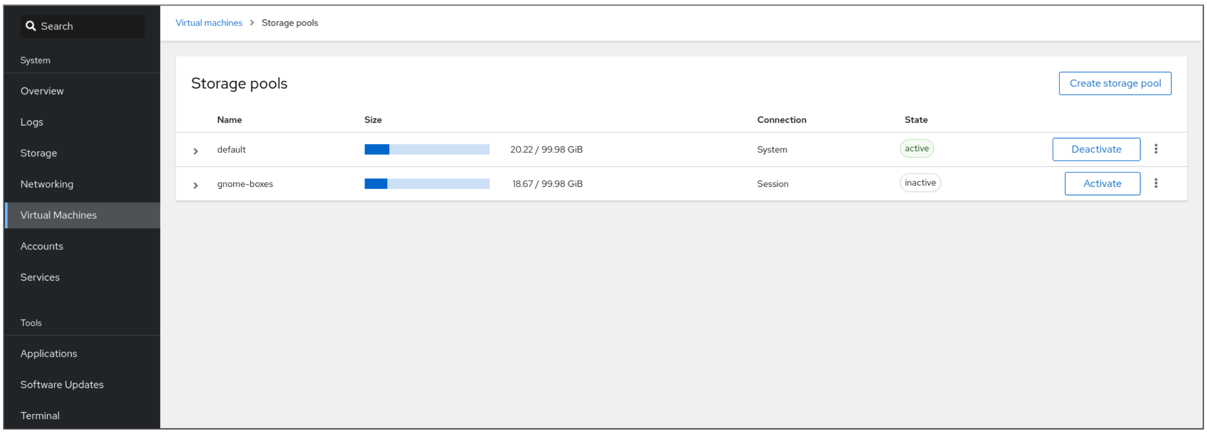
A directory-based storage pool is based on a directory in an existing mounted file system. This is useful, for example, when you want to use the remaining space on the file system for other purposes.

### Prerequisites

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

### Procedure

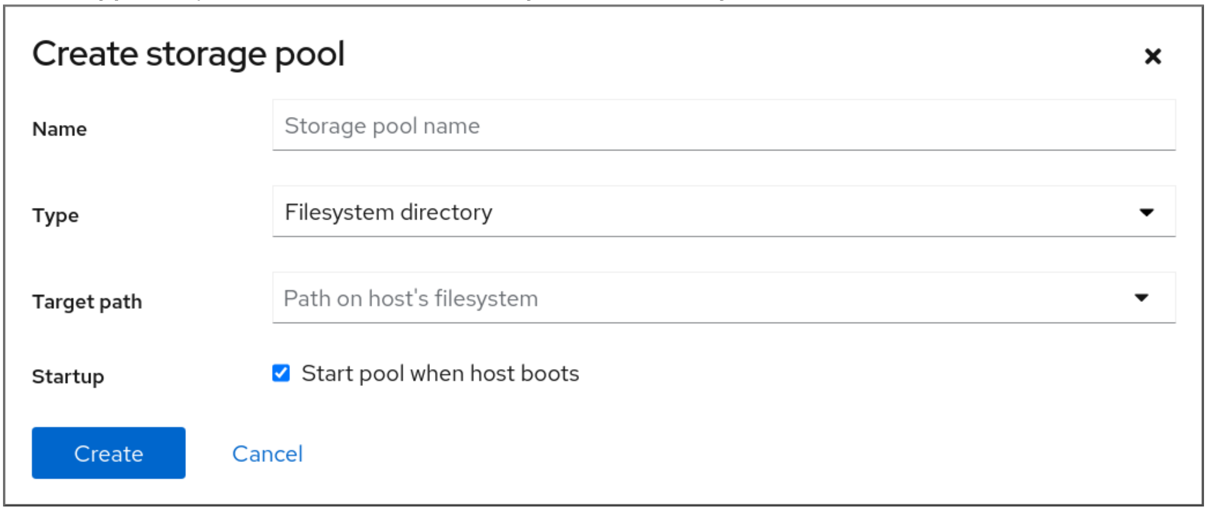
1. In the RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.




2. Click **Create storage pool**.
   The **Create storage pool** dialog appears.

3. Enter a name for the storage pool.

4. In the **Type** drop down menu, select **Filesystem directory**.




#### 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.

5. Enter the following information:
   - **Target path** - The source for the types of storage pools backed by directories, such as **dir** or **netfs**.
   - **Startup** - Whether or not the storage pool starts when the host boots.

6. 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

## 11.3.3. Creating NFS-based storage pools by using the web console

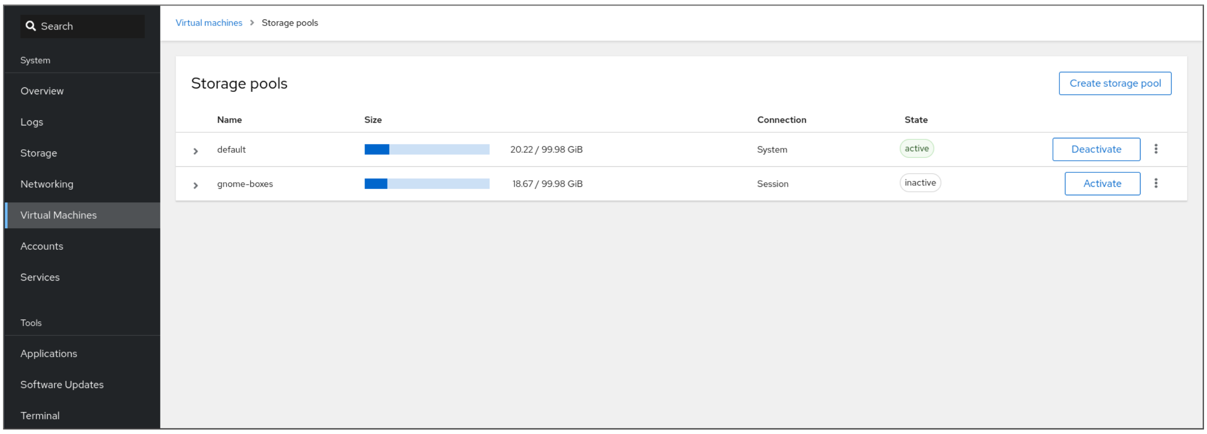
An NFS-based storage pool is based on a file system that is hosted on a server.

### Prerequisites

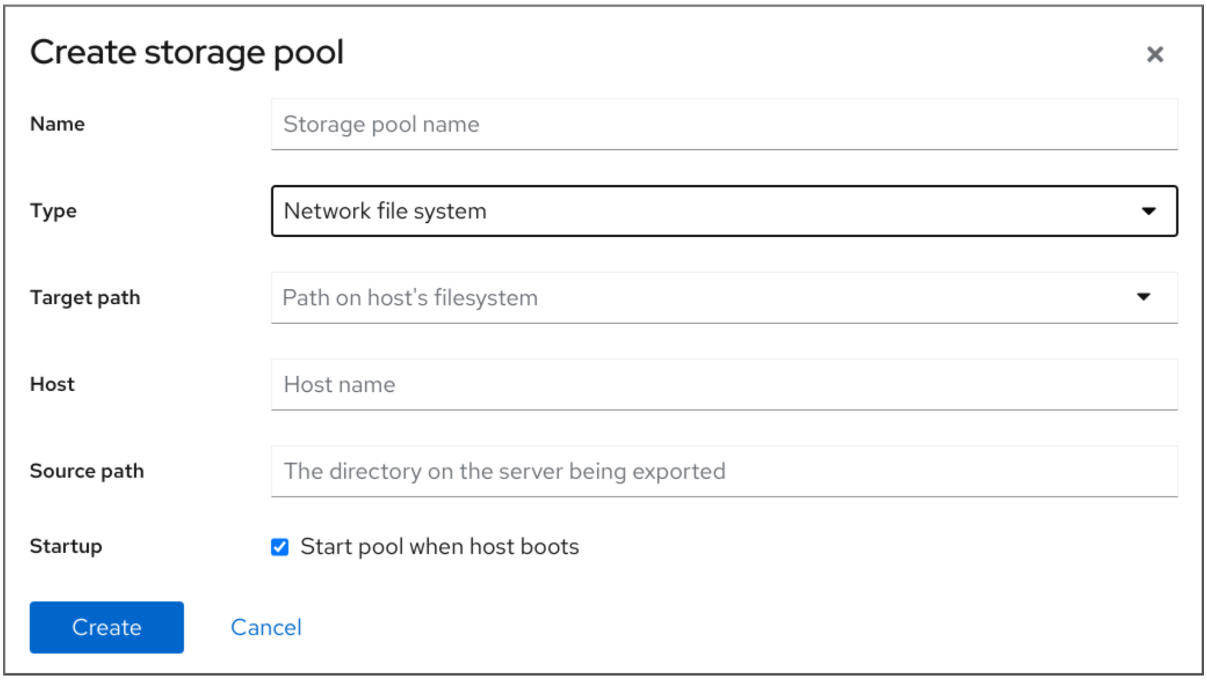
- The web console VM plug-in is installed on your system.

### Procedure

1. 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.




2. Click **Create storage pool**.
   The **Create storage pool** dialog appears.
3. Enter a name for the storage pool.
4. In the **Type** drop down menu, select **Network file system**.




> **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.

5. 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.
6. 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

## 11.3.4. Creating iSCSI-based storage pools by using the web console

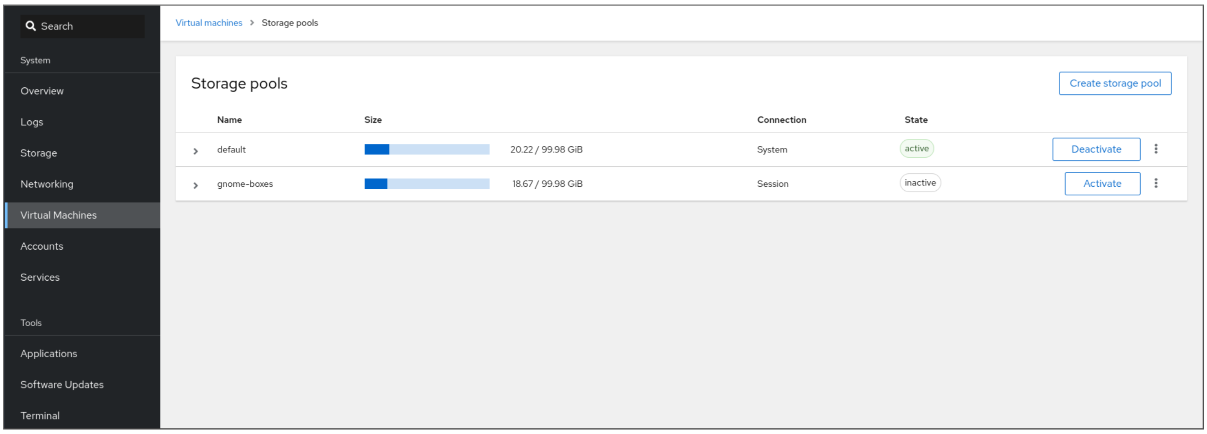
An iSCSI-based storage pool is based on the Internet Small Computer Systems Interface (iSCSI), an IP-based storage networking standard for linking data storage facilities.

### Prerequisites

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

### Procedure

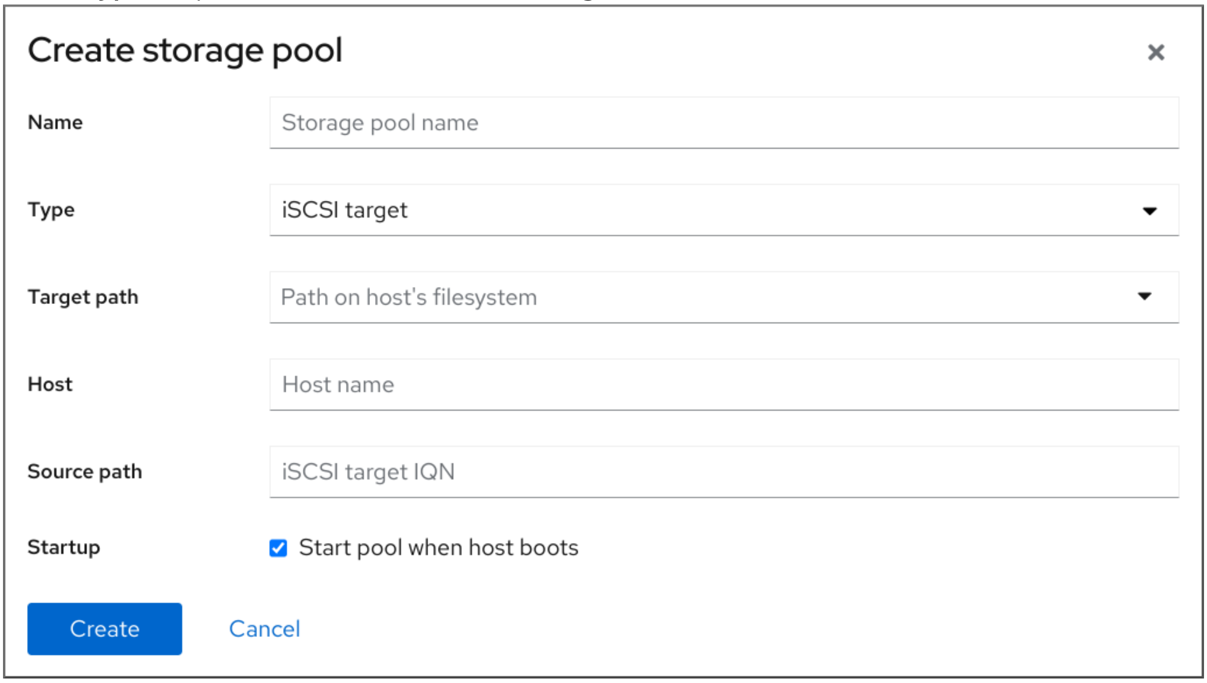
1. In the RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.




2. Click **Create storage pool**.
   The **Create storage pool** dialog appears.

3. Enter a name for the storage pool.

4. In the **Type** drop down menu, select **iSCSI target**.




5. 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.

6. Click **Create**.

   The storage pool is created. The **Create storage pool** dialog closes, and the new storage pool

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

## 11.3.5. Creating disk-based storage pools by using the web console

A disk-based storage pool uses entire disk partitions.

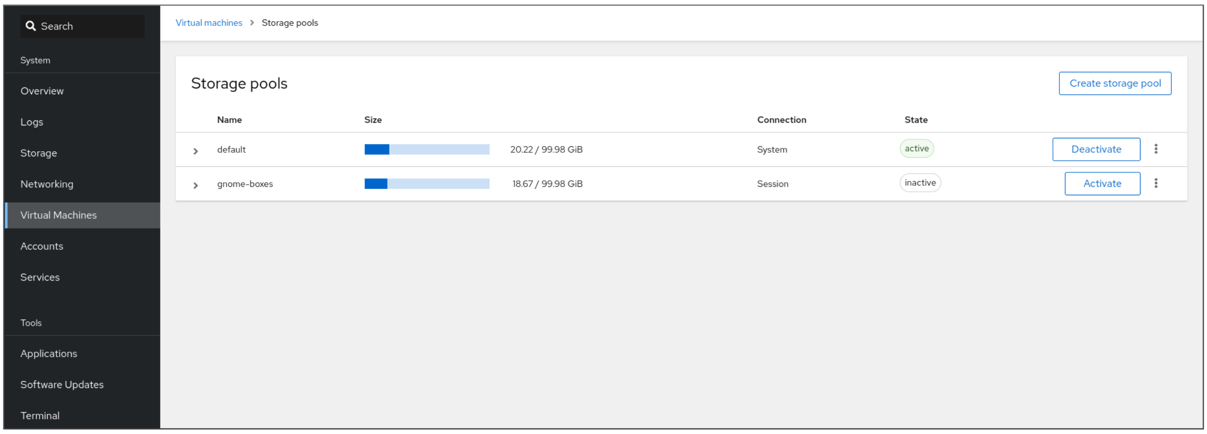
> **WARNING**
>
> - Depending on the version of libvirt being used, dedicating a disk to a storage pool may reformat and erase all data currently stored on the disk device. It is strongly recommended that you back up the data on the storage device before creating a storage pool.
> - When whole disks 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

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

### Procedure

1. 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.

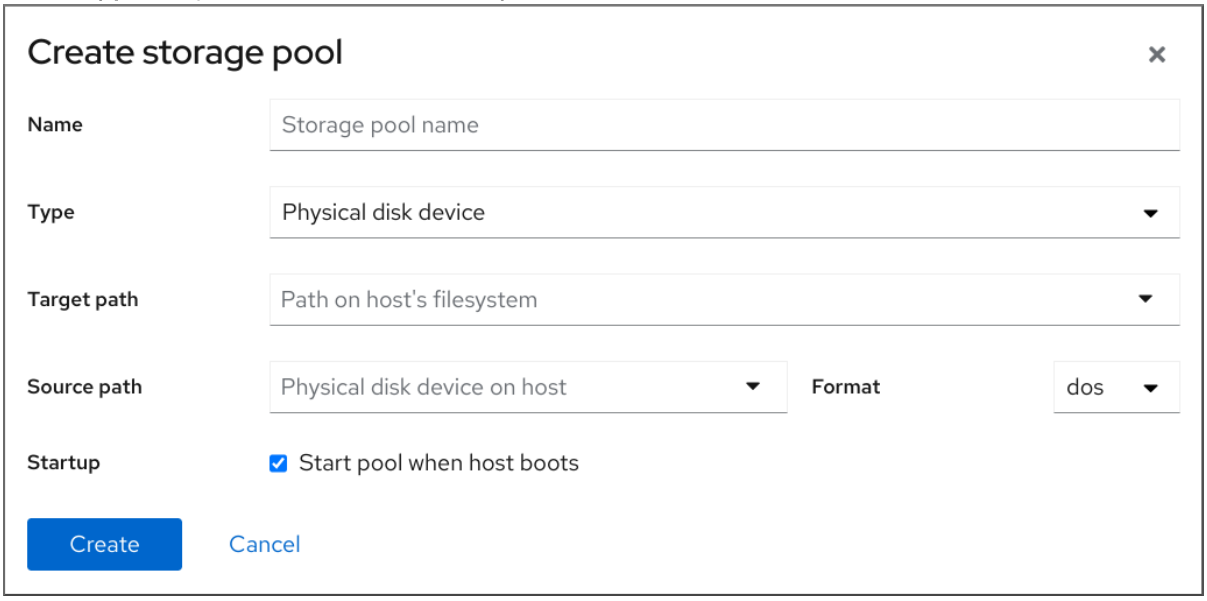



2. Click **Create storage pool**.

The **Create storage pool** dialog appears.

3. Enter a name for the storage pool.

4. In the **Type** drop down menu, select **Physical disk device**.




> **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.

5. 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.

6. 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

## 11.3.6. 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.

NOTE

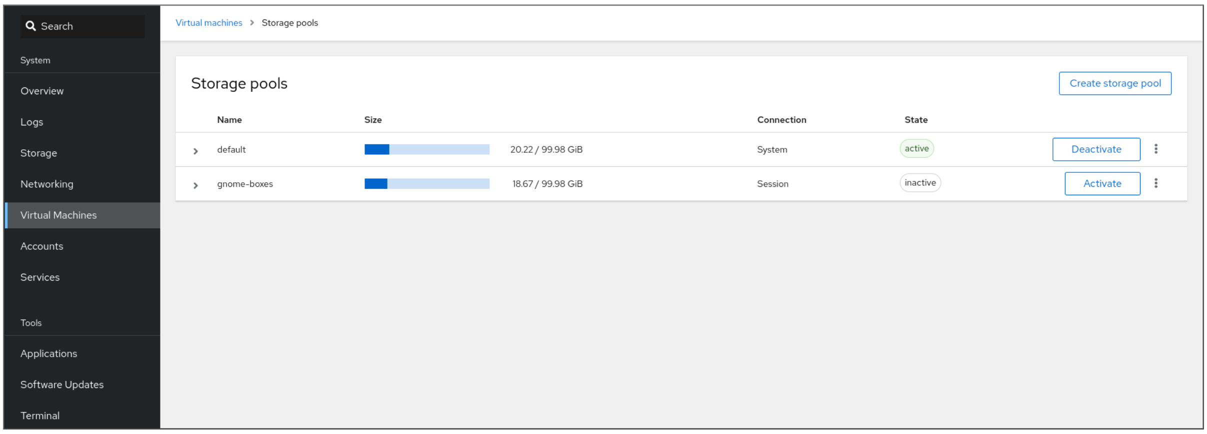
- LVM-based storage pools do not provide the full flexibility of LVM.
- **libvirt** supports thin logical volumes, but does not provide the features of thin storage pools.
- LVM-based storage pools require a full disk partition. If you activate a new partition or device by using **virsh** commands, the 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 the *Red Hat Enterprise Linux Logical Volume Manager Administration Guide*.

## Prerequisites

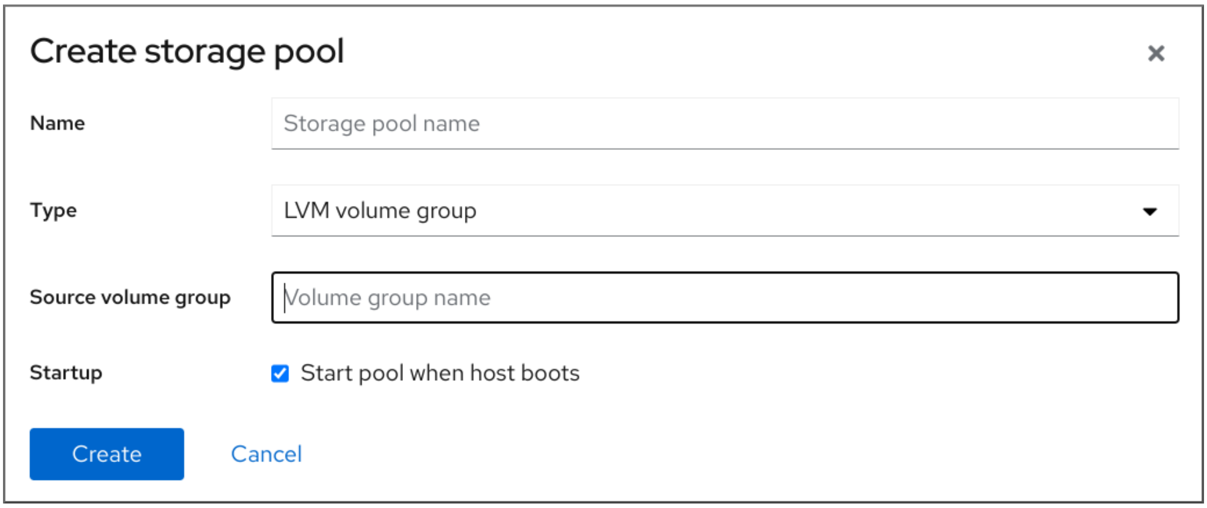
- The web console VM plug-in is installed on your system.

## Procedure

1. 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.




2. Click **Create storage pool**.
   The **Create storage pool** dialog appears.
3. Enter a name for the storage pool.
4. In the **Type** drop down menu, select **LVM volume group**.




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.

5. 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.
6. 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

### 11.3.7. Creating SCSI-based storage pools with vHBA devices by using the web console

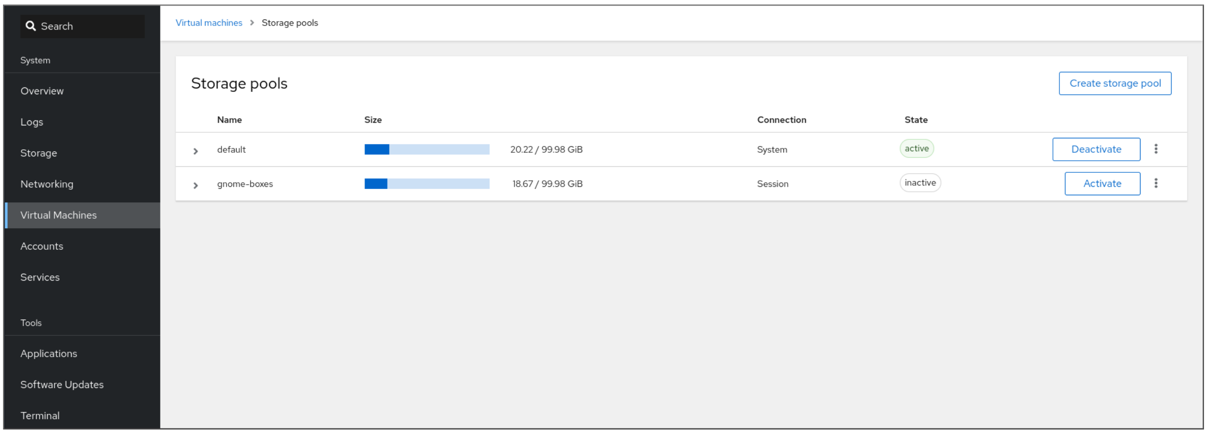
An SCSI-based storage pool is based on a Small Computer System Interface (SCSI) device. In this configuration, your host must be able to connect to the SCSI device by using a virtual host bus adapter (vHBA).

#### Prerequisites

- Create a vHBA. For more information, see Creating vHBAs.
- The web console VM plug-in is installed on your system.

#### Procedure

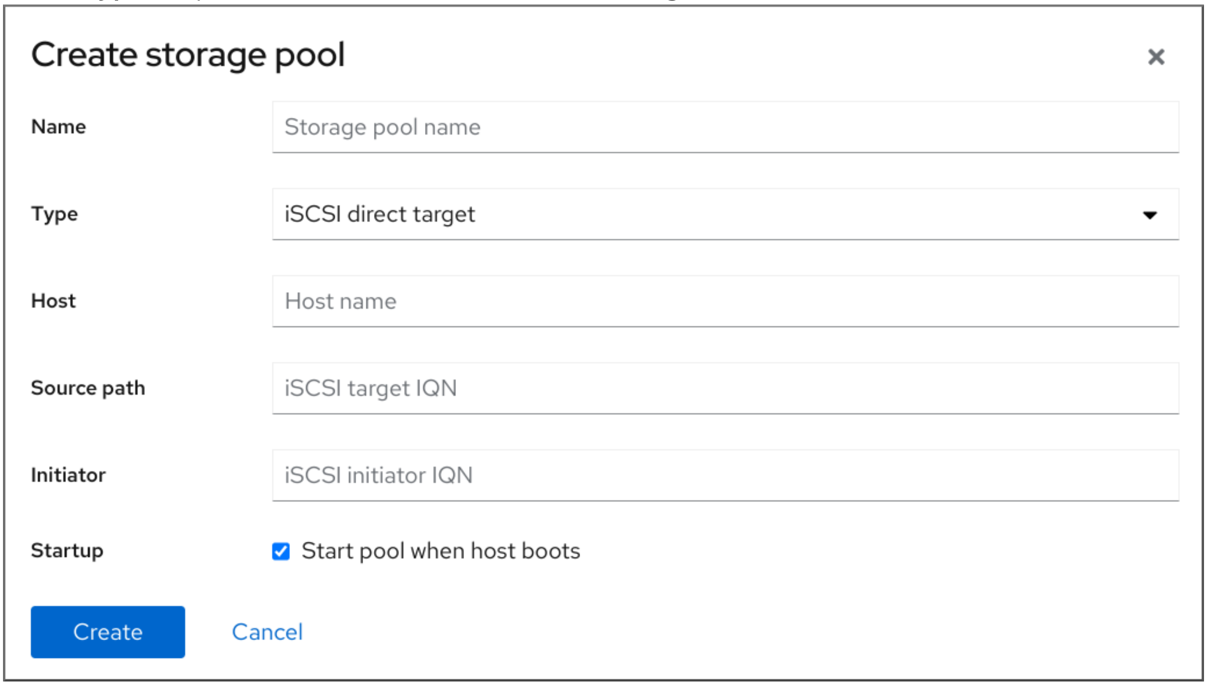
1. In the RHEL web console, click **Storage pools** in the **Virtual Machines** tab.
   The **Storage pools** window appears, showing a list of configured storage pools, if any.




2. Click **Create storage pool**.
The **Create storage pool** dialog appears.

3. Enter a name for the storage pool.

4. In the **Type** drop down menu, select **iSCSI direct target**




## NOTE

If you do not see the **iSCSI direct target** option in the drop down menu, then your hypervisor does not support SCSI-based storage pools.

5. Enter the rest of the information:
   - **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 unique iSCSI Qualified Name (IQN) of the iSCSI target.
   - **Initiator** - The unique iSCSI Qualified Name (IQN) of the iSCSI initiator, the vHBA.
   - **Startup** - Whether or not the storage pool starts when the host boots.

6. 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

## 11.3.8. Removing storage pools by using the web console

You can remove storage pools to free up resources on the host or on the network to improve system performance. Deleting storage pools also frees up resources that can then be used by other virtual machines (VMs).

> **IMPORTANT**
>
> Unless explicitly specified, deleting a storage pool does not simultaneously delete the storage volumes inside that pool.

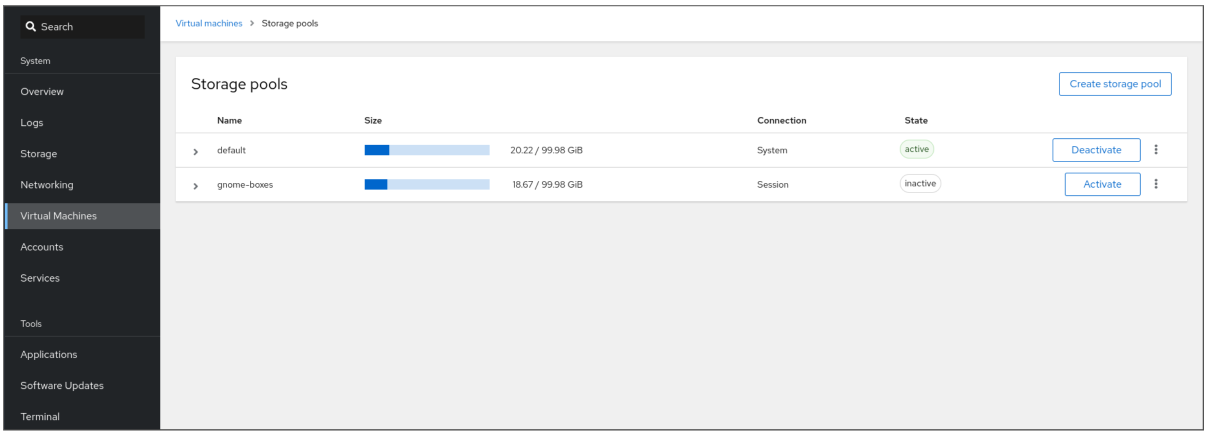
To temporarily deactivate a storage pool instead of deleting it, see Deactivating storage pools by using the web console

### Prerequisites

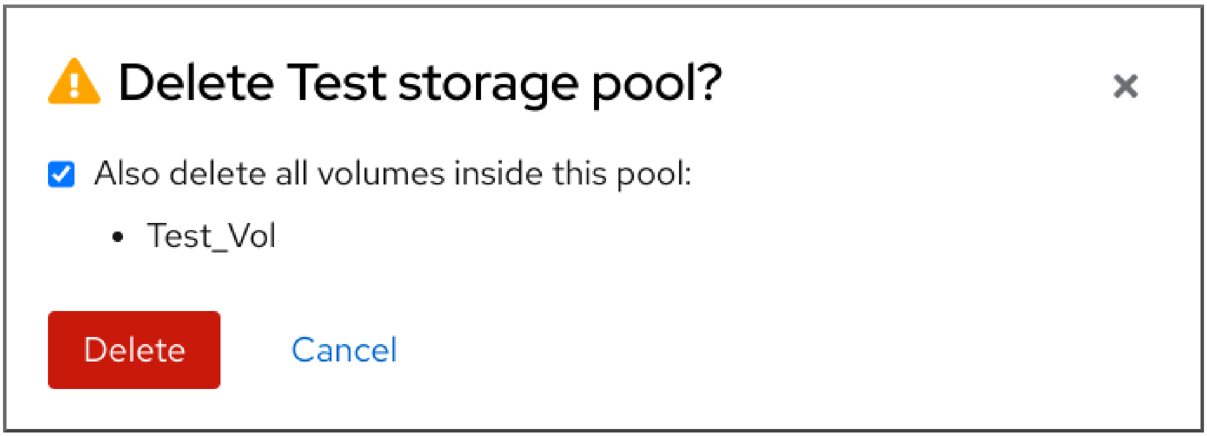
- The web console VM plug-in is installed on your system.
- Detach the disk from the VM.
- If you want to delete the associated storage volumes along with the pool, activate the pool.

### Procedure

1. Click **Storage Pools** on the **Virtual Machines** tab.
   The **Storage Pools** window appears, showing a list of configured storage pools.




2. Click the Menu button ⋮ of the storage pool you want to delete and click **Delete**.
   A confirmation dialog appears.




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

### 11.3.9. 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 a number of reasons, for example, you can limit the number of volumes that can be created in a pool to increase system performance.

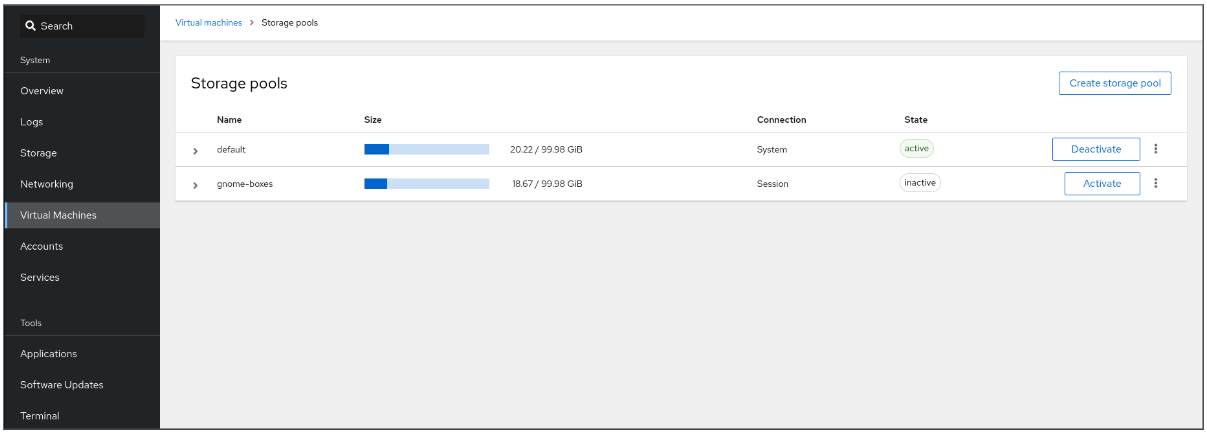
To deactivate a storage pool by using the RHEL web console, see the following procedure.

#### Prerequisites

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

#### 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.




2. 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

## 11.4. 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.

### 11.4.1. 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 11.1. Directory-based storage pool parameters**

| Description | XML |
|---|---|
| The type of storage pool | **<pool type='dir'>** |
| The name of the storage pool | **<name>*name*</name>** |

| Description | XML |
|---|---|
| The path specifying the target. This will be the path used for the storage pool. | `<target>`<br>`  <path>target_path</path>`<br>`</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

## 11.4.2. 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 11.2. Disk-based storage pool parameters**

| Description | XML |
|---|---|
| The type of storage pool | `<pool type='disk'>` |
| The name of the storage pool | `<name>name</name>` |
| The path specifying the storage device. For example, **/dev/sdb**. | `<source>`<br>`  <path>source_path</path>`<br>`</source>` |

| Description | XML |
| --- | --- |
| The path specifying the target device. This will be the path used for the storage pool. | **<target><br><path>*target_path*</path><br></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

## 11.4.3. 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 11.3. Filesystem-based storage pool parameters**

| Description | XML |
| --- | --- |
| The type of storage pool | **<pool type='fs'>** |
| The name of the storage pool | **<name>*name*</name>** |

| Description | XML |
|---|---|
| The path specifying the partition. For example, **/dev/sdc1** | **<source>**<br>**<device path=*device_path* />** |
| The file system type, for example **ext4**. | **<format type=*fs_type* />**<br>**</source>** |
| The path specifying the target. This will be the path used for the storage pool. | **<target>**<br>**<path>*path-to-pool*</path>**<br>**</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

## 11.4.4. GlusterFS-based storage pool parameters

When you want to create or modify a GlusterFS-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_glusterfs
```

### Parameters

The following table provides a list of required parameters for the XML file for a GlusterFS-based storage pool.

**Table 11.4. GlusterFS-based storage pool parameters**

| Description | XML |
| --- | --- |
| The type of storage pool | **<pool type='gluster'>** |
| The name of the storage pool | **<name>*name*</name>** |
| The hostname or IP address of the Gluster server | **<source><br><name=*gluster-name* />** |
| The path on the Gluster server used for the storage pool. | **<dir path=*gluster-path* /><br></source>** |

### Example

The following is an example of an XML file for a storage pool based on the Gluster file system at 111.222.111.222:

```
<pool type='gluster'>
  <name>Gluster_pool</name>
  <source>
    <host name='111.222.111.222'/>
    <dir path='/'/>
    <name>gluster-vol1</name>
  </source>
</pool>
```

### Additional resources

- Creating GlusterFS-based storage pools by using the CLI

## 11.4.5. 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 11.5. 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>**<br>**<host name=*hostname* />** |
| The iSCSI IQN | **<device path= *iSCSI_IQN* />**<br>**</source>** |
| The path specifying the target. This will be the path used for the storage pool. | **<target>**<br>**<path>*/dev/disk/by-path*</path>**<br>**</target>** |
| [Optional] The IQN of the iSCSI initiator. This is only needed when the ACL restricts the LUN to a particular initiator. | **<initiator>**<br>**<iqn name='*initiator0*' />**<br>**</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

## 11.4.6. 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 11.6. 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>**<br>**<device path='*device_path*' />`** |
| The name of the volume group | **<name>*VG-name*</name>** |
| The virtual group format | **<format type='lvm2' />**<br>**</source>** |
| The target path | **<target>**<br>**<path=*target_path* />**<br>**</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

### 11.4.7. 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 11.7. 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>**<br>**<host name=*hostname* />** |
| The format of the storage pool | One of the following:<br>**<format type='nfs' />**<br>**<format type='glusterfs' />**<br>**<format type='cifs' />** |
| The directory used on the network server | **<dir path=*source_path* />**<br>**</source>** |

| Description | XML |
| --- | --- |
| The path specifying the target. This will be the path used for the storage pool. | **<target><br><path>*target_path*</path><br></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

## 11.4.8. 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 11.8. 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>** |

| Description | XML |
|---|---|
| The identifier of the vHBA. The **parent** attribute is optional. | **<source><br><adapter type='fc_host'<br>[parent=*parent_scsi_device*]<br>wwnn='*WWNN*'<br>wwpn='*WWPN*' /><br></source>** |
| The target path. This will be the path used for the storage pool. | **<target><br><path=*target_path* /><br></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

## 11.5. 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

### 11.5.1. 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.

```
# vol-info --pool RHEL-Storage-Pool --vol RHEL_Volume.qcow2
Name:          RHEL_Volume.qcow2
Type:          file
Capacity:      60.00 GiB
Allocation:    13.93 GiB
```

### 11.5.2. 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:

   - **GlusterFS-based** - Use the **qemu-img** command 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 *GlusterFS-based* pools:

```
<disk type='network' device='disk'>
  <driver name='qemu' type='raw'/>
  <source protocol='gluster' name='Volume1/Image'>
    <host name='example.org' port='6000'/>
  </source>
  <target dev='vda' bus='virtio'/>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x03' function='0x0'/>
</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.

## 11.5.3. 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
```

## 11.6. 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.

### 11.6.1. 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 have 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

### 11.6.2. 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. Repair them by using 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

- The **qemu-img** man page
- The **guestfish** man page

### 11.6.3. 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 back up 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

- The **qemu-img** man page
- Managing storage devices
- Managing file systems

### 11.6.4. 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.

#### Procedure

- Use the **qemu-im 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
- The **qemu-img** man page

## 11.7. 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.

### 11.7.1. 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.

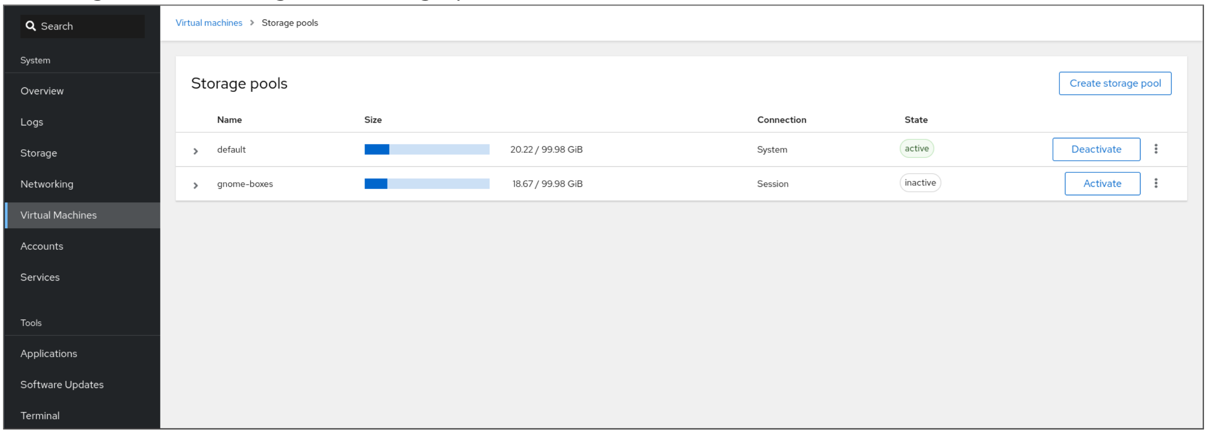
To create storage volumes by using the web console, see the following procedure.

#### Prerequisites

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

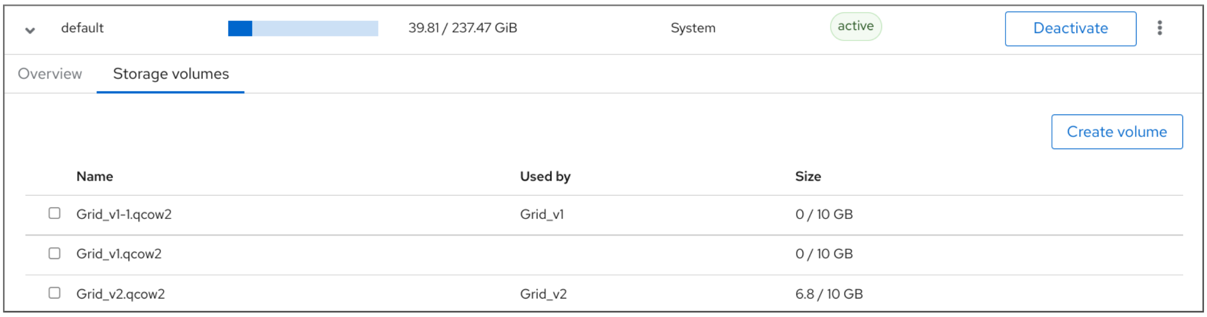
#### Procedure

1. Click **Storage Pools** at the top of the Virtual Machines tab. The Storage Pools window appears, showing a list of configured storage pools.




2. 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.


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.




4. Click **Create Volume**.
   The **Create storage volume** dialog appears.


5. 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**.

6. 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

### 11.7.2. 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).

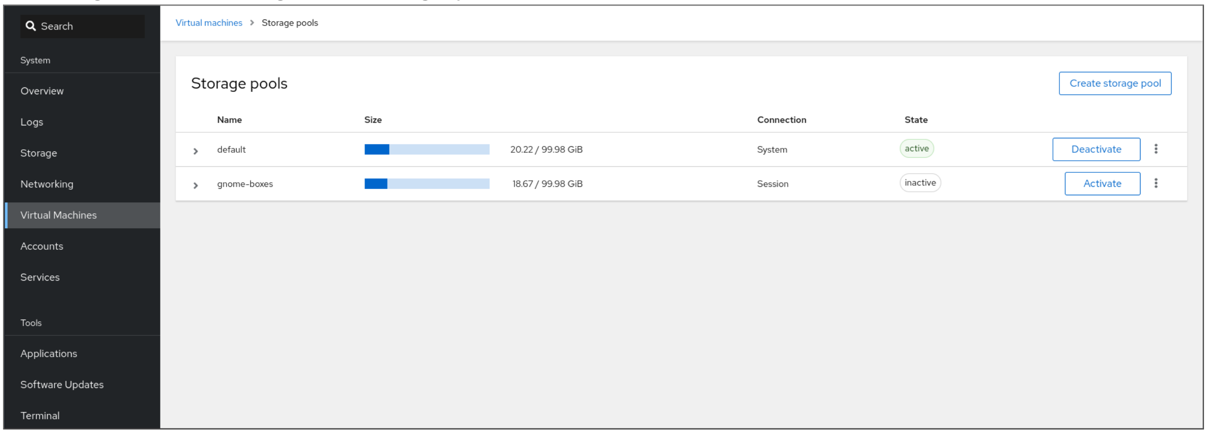
To remove storage volumes by using the RHEL web console, see the following procedure.

#### Prerequisites

- 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.

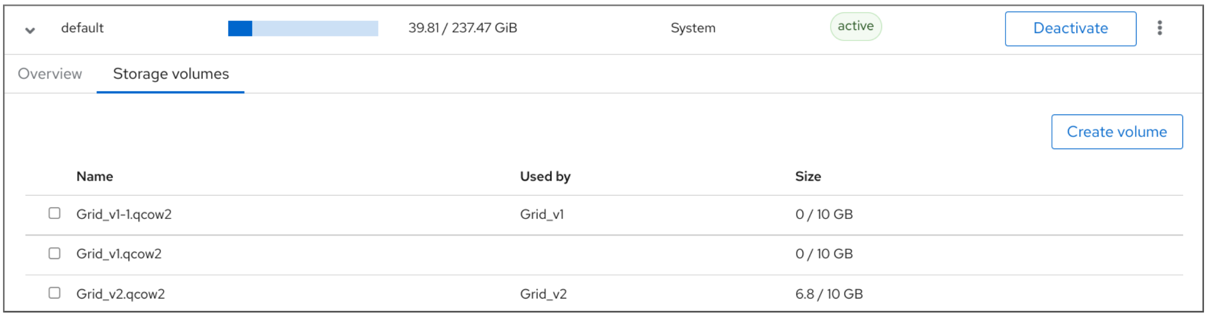
#### Procedure

1. Click **Storage Pools** at the top of the Virtual Machines tab. The Storage Pools window appears, showing a list of configured storage pools.

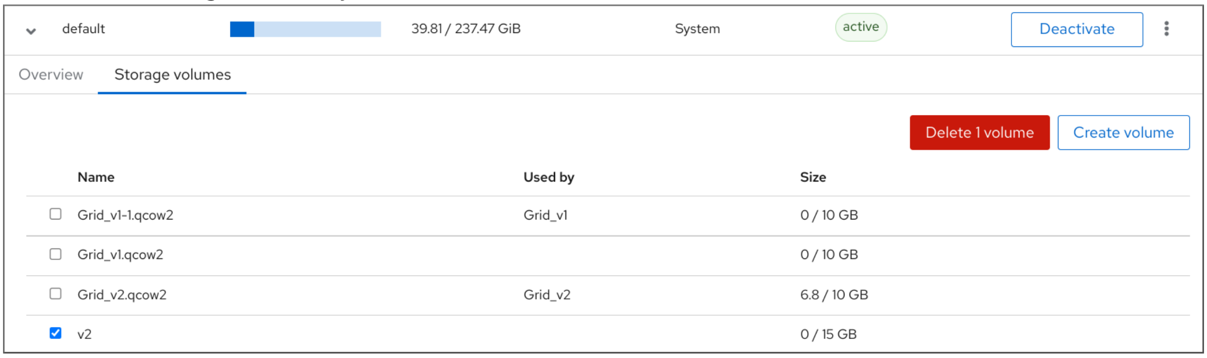



2. In the **Storage Pools** window, click the storage pool from which you want to remove a storage volume.
   The row expands to reveal the Overview pane with basic information about the selected storage pool.

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.




4. Select the storage volume you want to remove.




5. Click **Delete 1 Volume**

### Additional resources

- Understanding storage volumes

## 11.8. 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 .

### 11.8.1. 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).

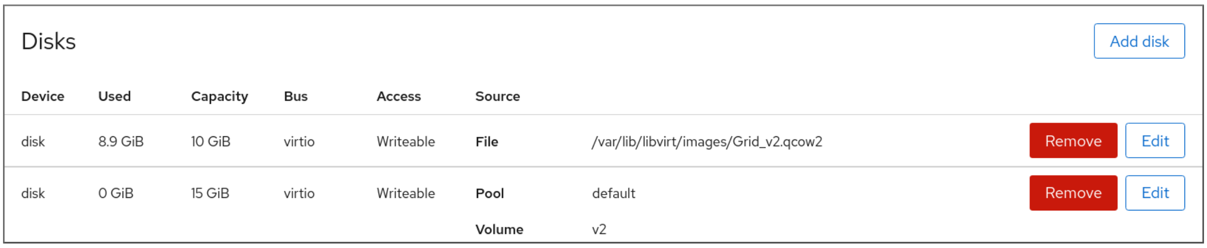
#### Prerequisites

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

### Procedure

1. 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.

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




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

## 11.8.2. 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 8 web console.

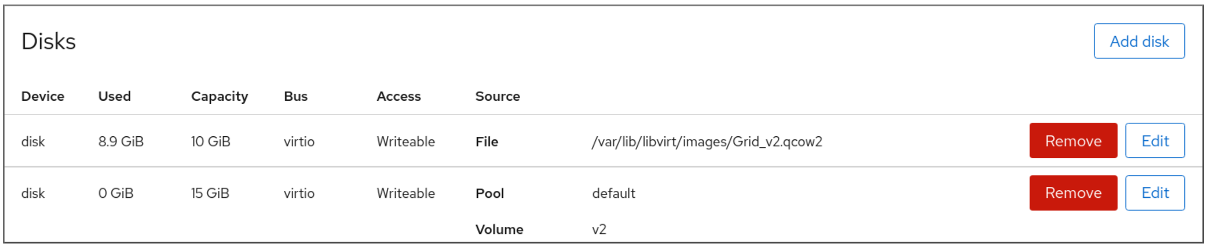
### Prerequisites

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

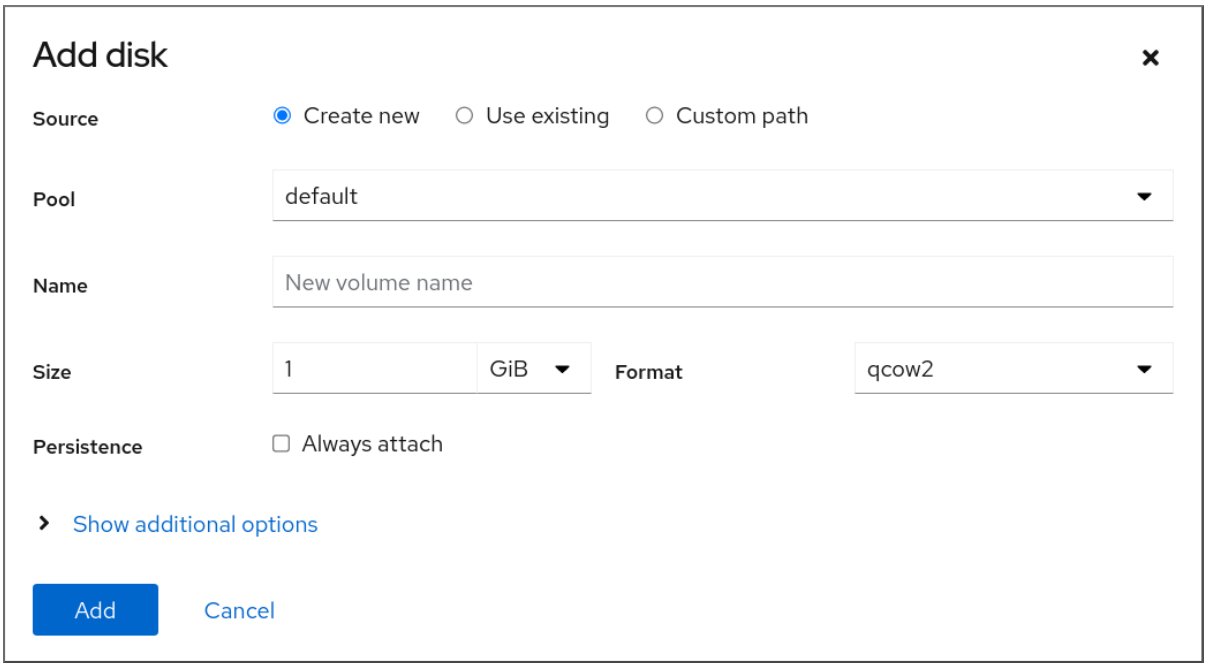
### Procedure

1. 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.

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




3. Click **Add Disk**.
   The Add Disk dialog appears.




4. Select the *Create New* option.

5. 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.

6. 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

## 11.8.3. 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).

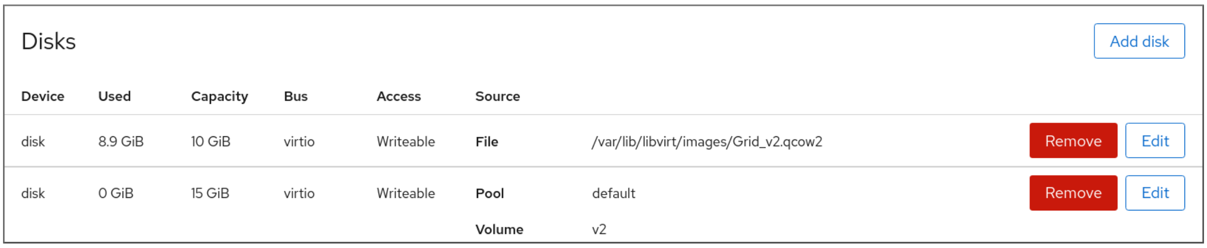
### Prerequisites

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

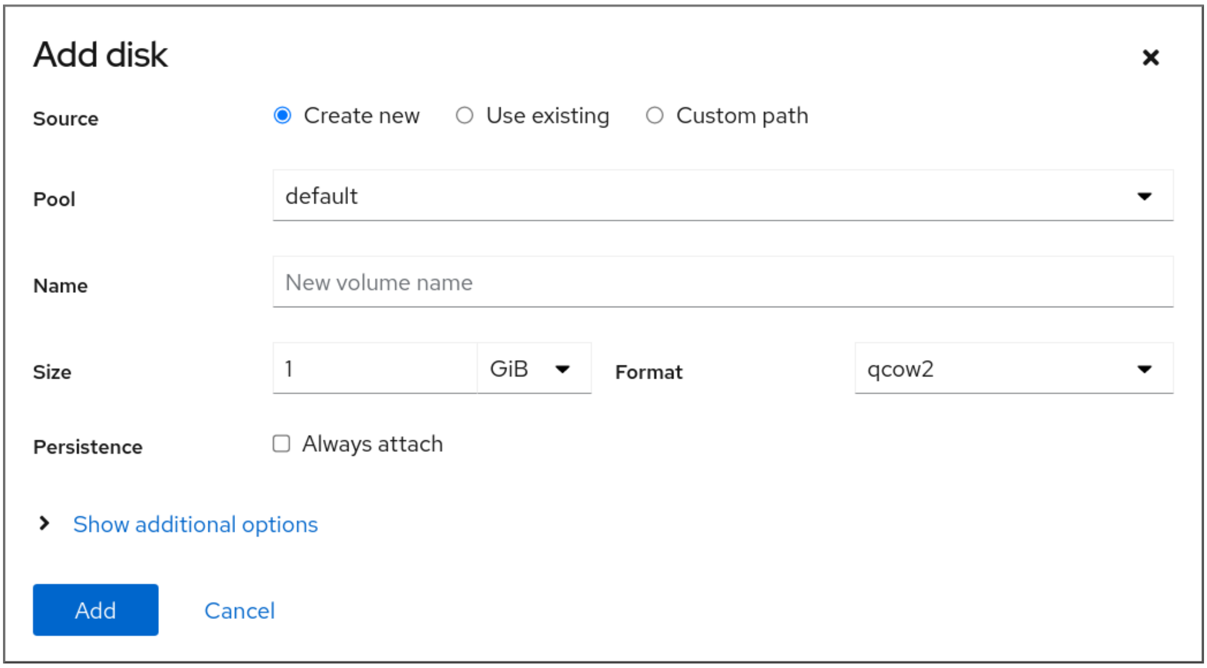
### Procedure

1. 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.

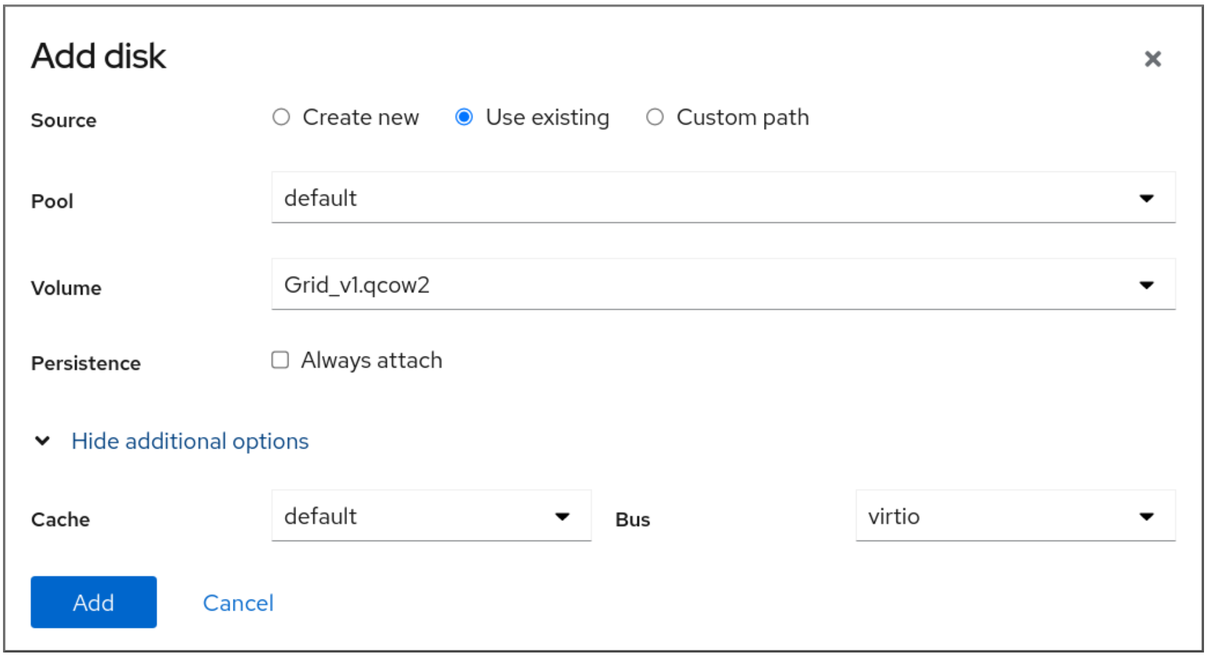
2. Scroll to **Disks**.
   The Disks section displays information about the disks assigned to the VM as well as options to **Add**, **Remove**, or **Edit** disks.




3. Click **Add Disk**.
   The Add Disk dialog appears.




4. Click the **Use Existing** radio button.
   The appropriate configuration fields appear in the Add Disk dialog.




5. 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.

6. 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

### 11.8.4. Detaching disks from virtual machines by using the web console

By using the web console, you can detach disks from virtual machines (VMs).

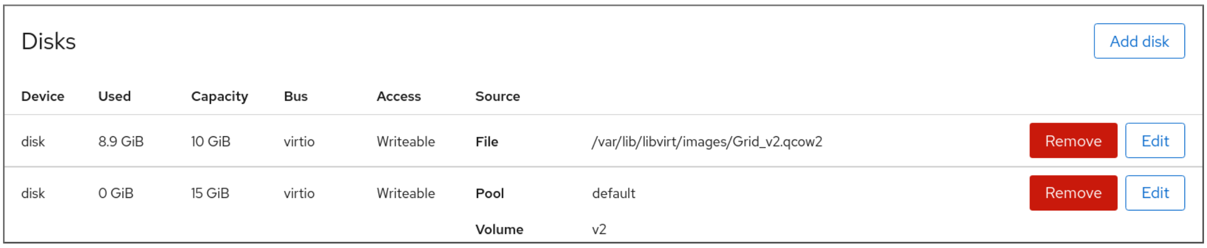
### Prerequisites

- 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**, **Remove**, or **Edit** disks.




3. Click the **Remove** button next to the disk you want to detach from the VM. A **Remove Disk** confirmation dialog box appears.

4. In the confirmation dialog box, click **Remove**.
   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

## 11.9. 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
```

## 11.10. 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 nodedev-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 12. MANAGING GPU DEVICES IN VIRTUAL MACHINES

To enhance the graphical performance of your virtual machine (VMs) on a RHEL 8 host, you can assign a host GPU to a 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, and only one mediated device can be assigned to a single guest.

## 12.1. 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.

### 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

- The number of GPUs that can be attached to a VM is limited by the maximum number of assigned PCI devices, which in RHEL 8 is currently 64. However, attaching multiple GPUs to a VM is likely to cause problems with memory-mapped I/O (MMIO) on the guest, which may result in the GPUs not being available to the VM.
To work around these problems, set a larger 64-bit MMIO space and configure the vCPU physical address bits to make the extended 64-bit MMIO space addressable.

- Attaching an NVIDIA GPU device to a VM that uses a RHEL 8 guest operating system currently disables the Wayland session on that VM, and loads an Xorg session instead. This is because of incompatibilities between NVIDIA drivers and Wayland.

## 12.2. 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.

### 12.2.1. 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_d196754e_d8ed_4f43_bf22_684ed698b08b_0000_9b_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.

```
<hostdev mode='subsystem' type='mdev' managed='no' model='vfio-pci' display='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. In addition, if the VM does not have QEMU video devices, such as **virtio-vga**, add also the **ramfb='on'** parameter on the **<hostdev>** line.

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 8 guest operating system currently disables the Wayland session on that VM, and loads an Xorg session instead. This is because of incompatibilities between NVIDIA drivers and Wayland.

### Additional resources

- NVIDIA vGPU software documentation
- The **man virsh** command

## 12.2.2. 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

- The **man virsh** command

## 12.2.3. 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

### 12.2.4. Remote desktop streaming services for NVIDIA vGPU

The following remote desktop streaming services are supported on the RHEL 8 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.

### 12.2.5. Additional resources

- NVIDIA vGPU software documentation

# CHAPTER 13. 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 8 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.

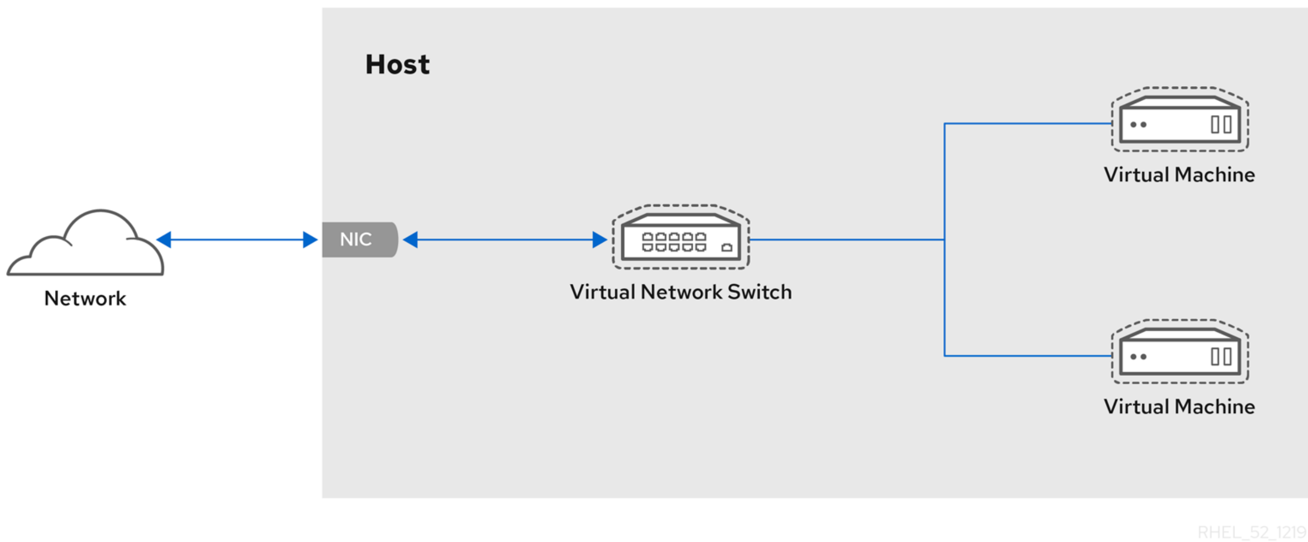
## 13.1. UNDERSTANDING VIRTUAL NETWORKING

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.

### 13.1.1. 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 **libvirtd** 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 **libvirtd** 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:

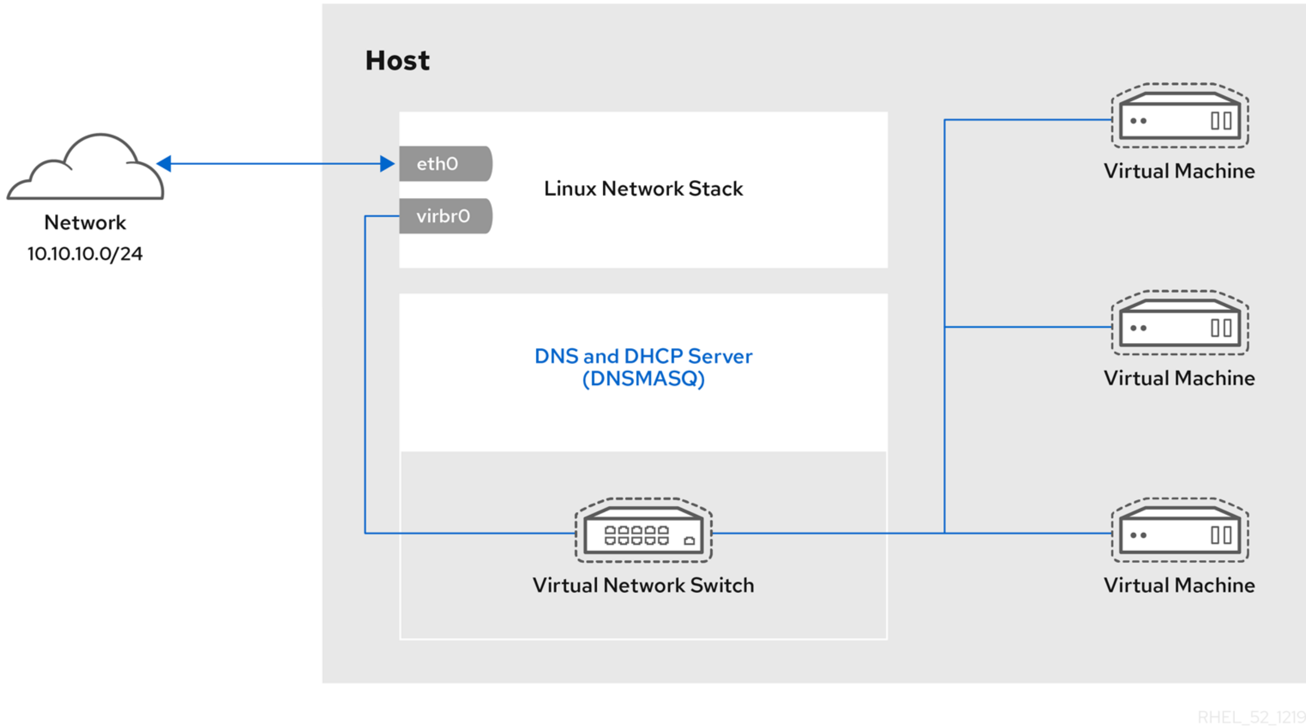
- Routed mode
- Bridged mode
- Isolated mode
- Open mode

### 13.1.2. Virtual networking default configuration

When the **libvirtd** 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:




## 13.2. USING THE WEB CONSOLE FOR MANAGING VIRTUAL MACHINE NETWORK INTERFACES

Using the RHEL 8 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.

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

By using the RHEL 8 web console, you can view and modify the virtual network interfaces on a selected virtual machine (VM):

#### Prerequisites

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

#### Procedure

1. 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.

2. 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.


The information includes the following:

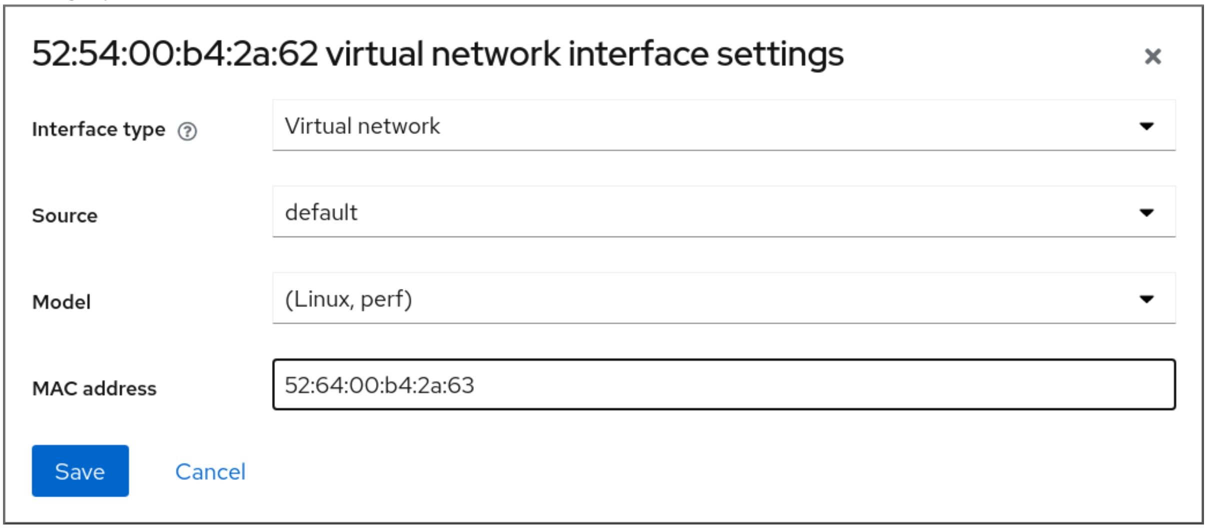
- **Type** - The type of network interface for the VM. The types include virtual network, bridge to LAN, and direct attachment.

  NOTE

  Generic Ethernet connection is not supported in RHEL 8 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.

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




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

### 13.2.2. Adding and connecting virtual network interfaces in the web console

By using the RHEL 8 web console, you can create a virtual network interface and connect a virtual machine (VM) to it.

#### Prerequisites

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

#### Procedure

1. 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.

2. 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 **Plug** network interfaces.


3. Click **Plug** in the row of the virtual network interface you want to connect.
   The selected virtual network interface connects to the VM.

### 13.2.3. Disconnecting and removing virtual network interfaces in the web console

By using the RHEL 8 web console, you can disconnect the virtual network interfaces connected to a selected virtual machine (VM).

#### Prerequisites

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

#### Procedure

1. 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.

2. 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.

3. Click **Unplug** in the row of the virtual network interface you want to disconnect.
   The selected virtual network interface disconnects from the VM.

## 13.3. 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 interface (CLI) or the RHEL 8 web console to do so. The following sections describe selected VM network setups for such situations.

### 13.3.1. Configuring externally visible virtual machines by using the command-line interface

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 interface 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 8, 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

### 13.3.2. 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 8 web console for this, follow the instructions below.

#### Prerequisites

- 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.


Interfaces

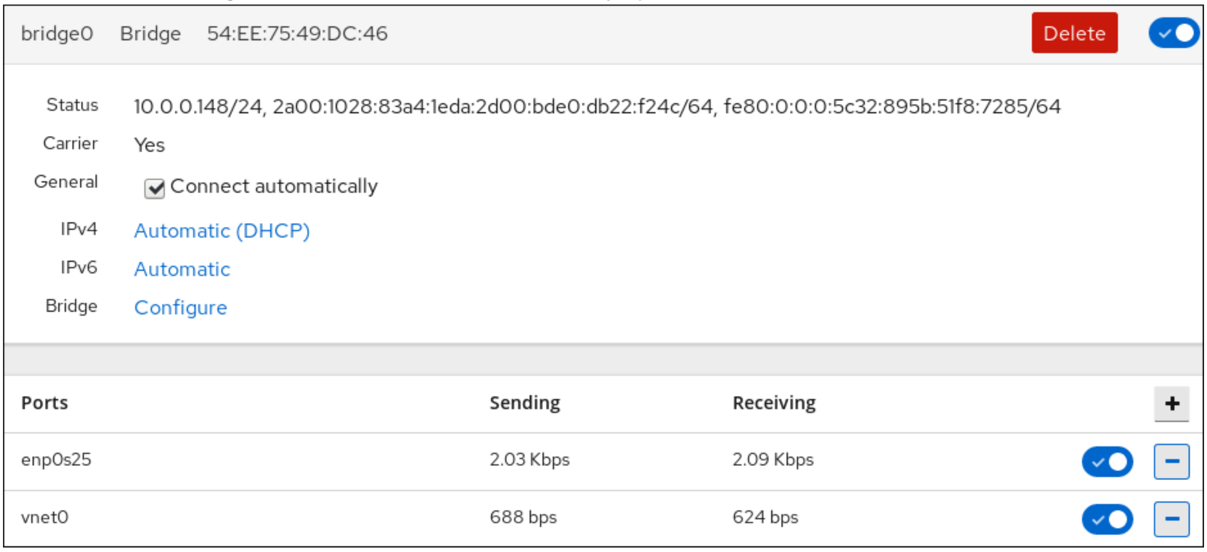
| Name | IP Address | Sending |
|---|---|---|
| enp0s25 | 10.0.0.148/24, 2a00:1028:83a4:1eda:91c7:667:8845:fa2e/64 | 2.29 Mbps |

#### 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 8, 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.

To work around this problem, you can set destination NAT by using **nftables** for the VM.

### Additional resources

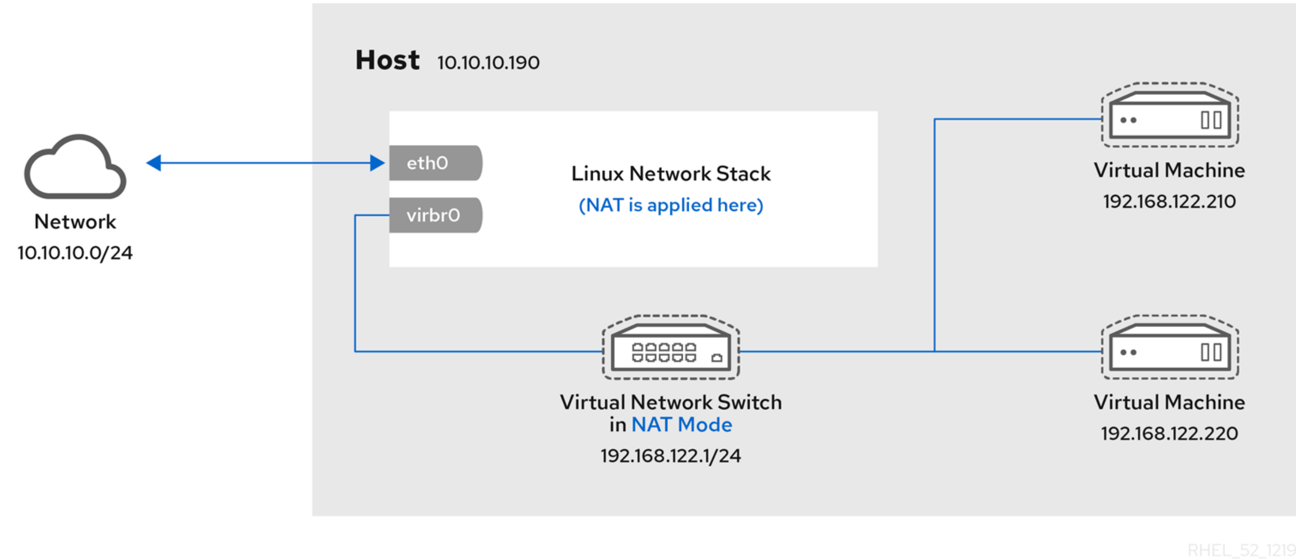
- Configuring externally visible virtual machines by using the command-line interface
- Virtual networking in bridged mode

## 13.4. 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 8.

### 13.4.1. 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.

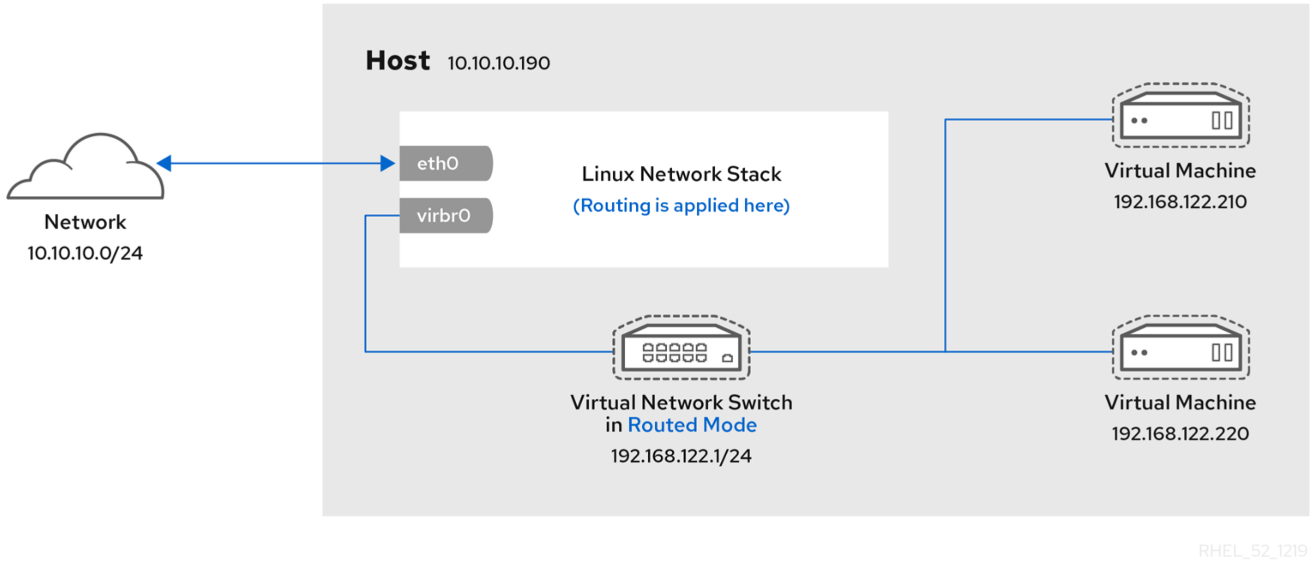



> **WARNING**
>
> Virtual network switches use NAT configured by firewall rules. Editing these rules while the switch is running is not recommended, because incorrect rules may result in the switch being unable to communicate.

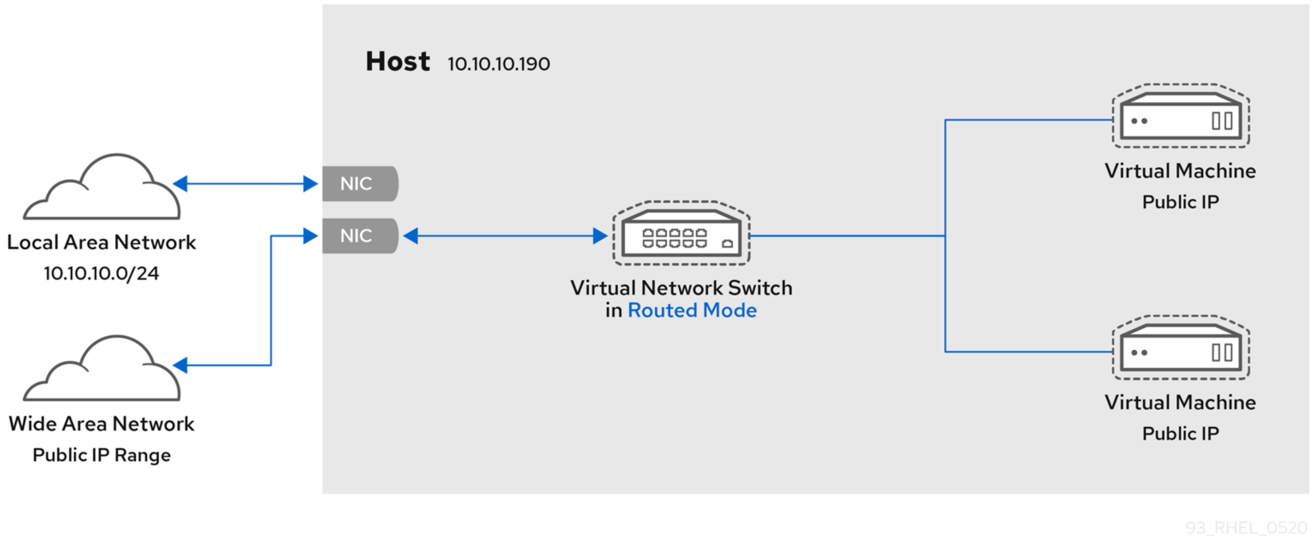
### 13.4.2. Virtual networking in routed mode

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:



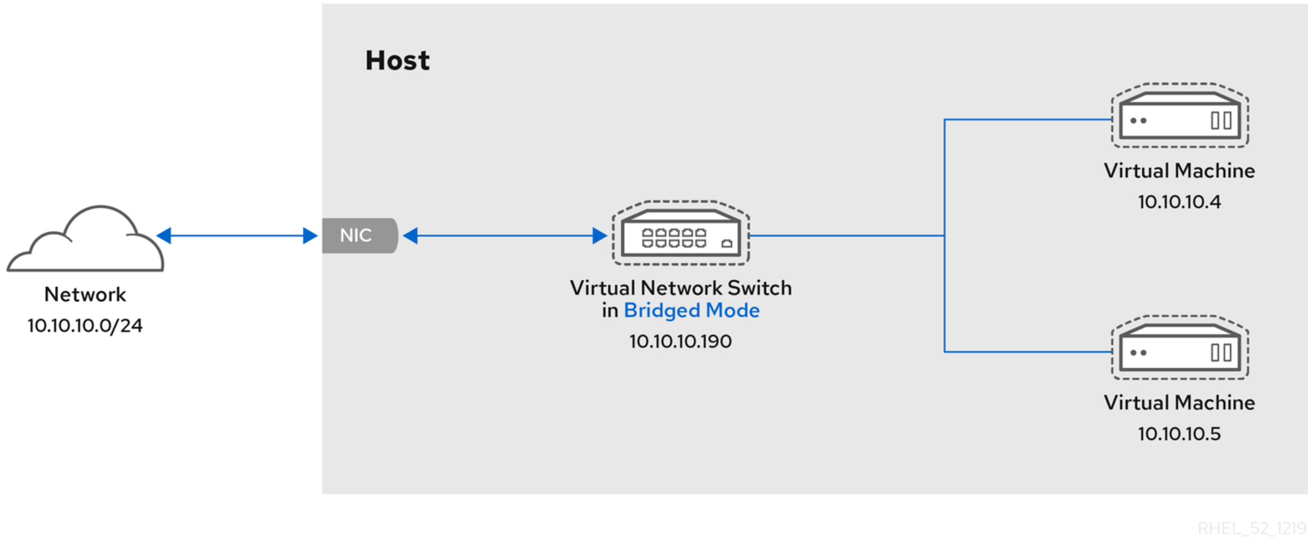

A common topology that uses routed mode is virtual server hosting (VSH). A VSH provider may have several host machines, each with two physical network connections. One interface is used for management and accounting, the other for the VMs to connect through. Each VM has its own public IP address, but the host machines use private IP addresses so that only internal administrators can manage the VMs.




### 13.4.3. 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, refer to the Red Hat Knowledgebase .

### Common scenarios

The most common use cases for bridged mode include:

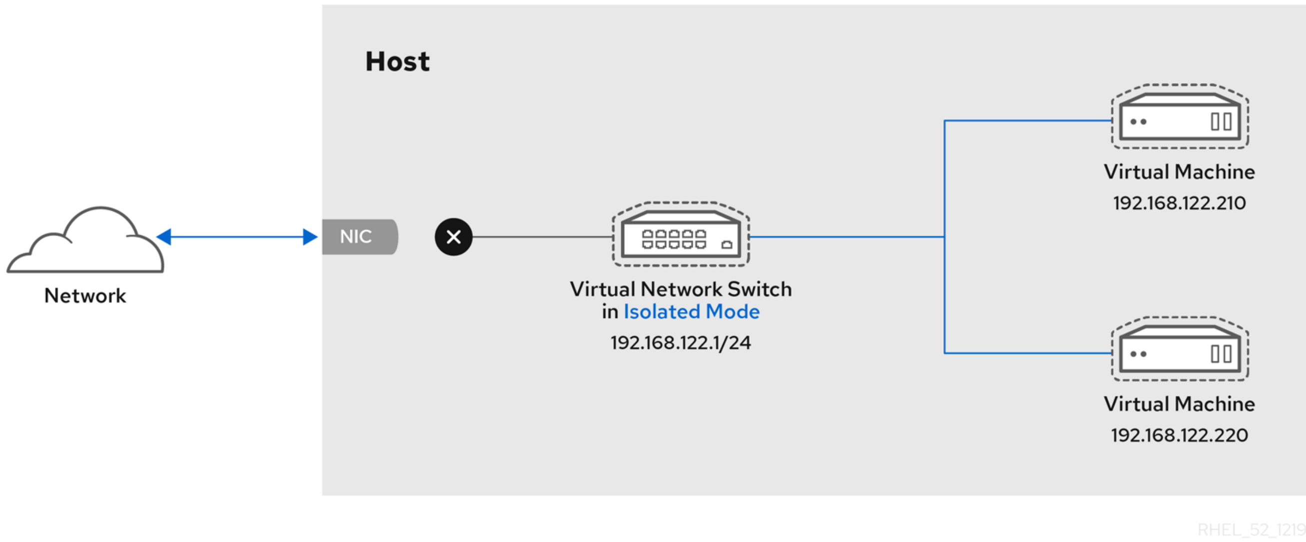
- Deploying VMs in an existing network alongside host machines, making the difference between virtual and physical machines invisible to the end user.
- Deploying VMs without making any changes to existing physical network configuration settings.
- Deploying VMs that must be easily accessible to an existing 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 interface
- Configuring externally visible virtual machines by using the web console
- Explanation of **bridge_opts** parameters

## 13.4.4. 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.




## 13.4.5. 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.

## 13.4.6. 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 13.1. 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 |

| | Connection to the host | Connection to other VMs on the host | Connection to outside locations | Visible to outside locations |
|---|---|---|---|---|
| **Isolated mode** | YES | YES | *no* | *no* |
| **Open mode** | *Depends on the host's firewall rules* | | | |

## 13.5. 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.

### 13.5.1. 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 to install from the network by using PXE

## 13.5.2. 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:

    i. Ensure the **<os>** element has a **<boot dev='network'/>** element inside:

```
<os>
  <type arch='x86_64' machine='pc-i440fx-rhel7.0.0'>hvm</type>
  <boot dev='network'/>
  <boot dev='hd'/>
</os>
```

    ii. Ensure the guest network is configured to use your virtual network:

```
<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'/>
</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.

## 13.5.3. 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:

    i. Ensure the **<os>** element has a **<boot dev='network'/>** element inside:

```
<os>
  <type arch='x86_64' machine='pc-i440fx-rhel7.0.0'>hvm</type>
  <boot dev='network'/>
  <boot dev='hd'/>
</os>
```

ii. Ensure the VM is configured to use your bridged network:

```
<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'/>
</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

## 13.6. ADDITIONAL RESOURCES

- Configuring and managing networking
- Attach specific network interface cards as SR-IOV devices to increase VM performance.

# CHAPTER 14. 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.

## 14.1. SHARING FILES BETWEEN THE HOST AND ITS VIRTUAL MACHINES BY USING NFS

For efficient file sharing between the RHEL 8 host system and the virtual machines (VMs), you can export an NFS share that VMs can mount and access.

### Prerequisites

- The **nfs-utils** package is installed on the host.

  ```
  # yum 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

# CHAPTER 15. SECURING VIRTUAL MACHINES

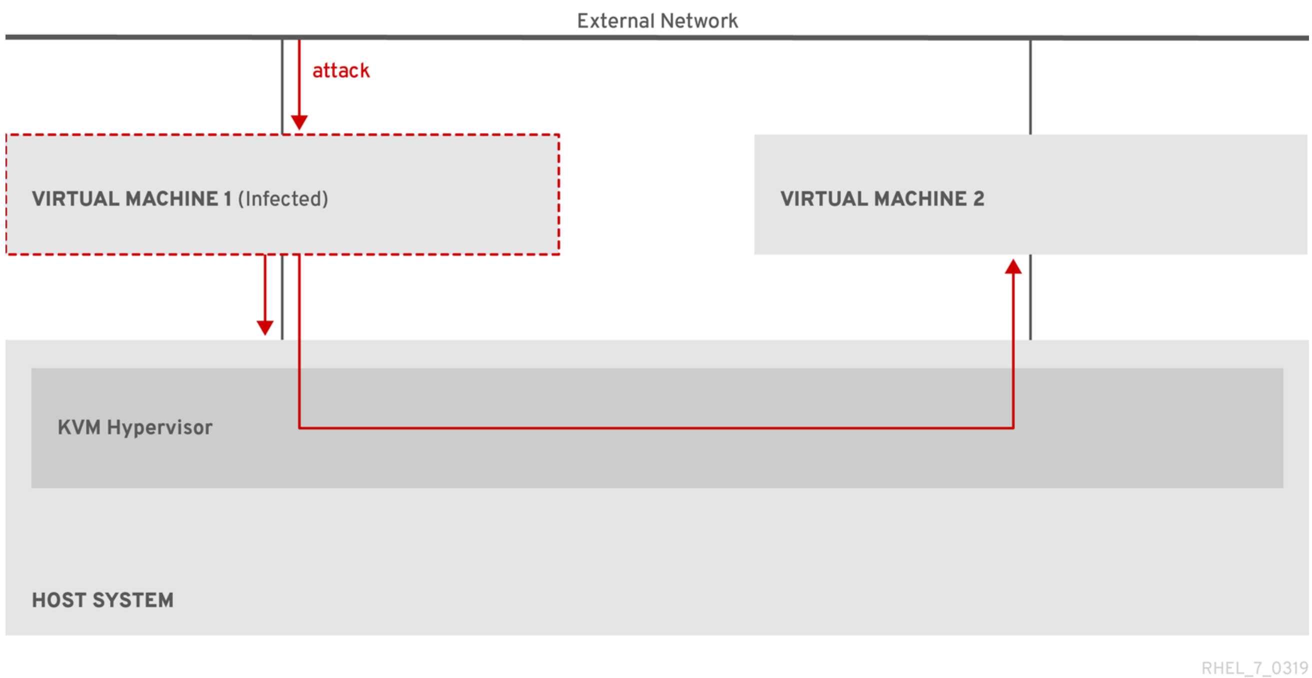
As an administrator of a RHEL 8 system with virtual machines (VMs), ensuring that your VMs are as secure as possible significantly lowers the risk of your guest and host OSs being infected by malicious software.

This document outlines the mechanics of securing VMs on a RHEL 8 host and provides a list of methods to increase the security of your VMs.

## 15.1. 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.

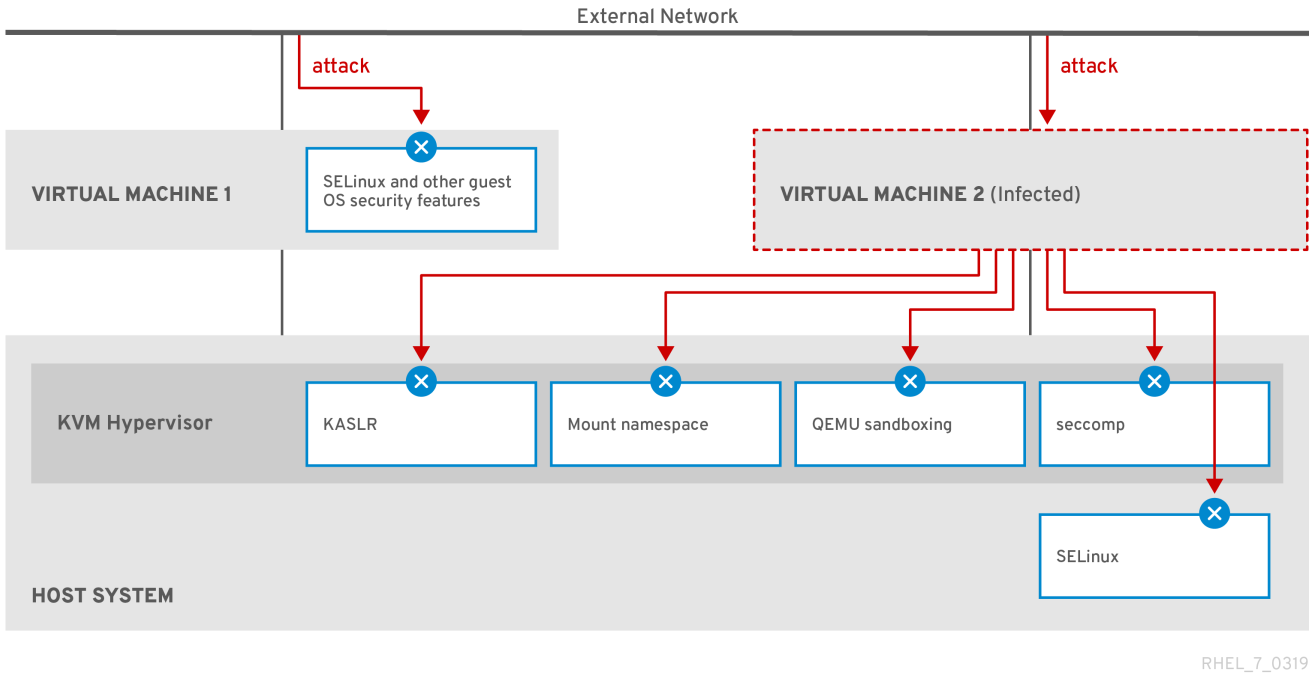
**Figure 15.1. A potential malware attack vector on a virtualization host**




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 15.2. Prevented malware attacks on a virtualization host**




Many of the features that RHEL 8 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 .

## 15.2. 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 8, see Securing Red Hat Enterprise Linux 8 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 8 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. 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 8, 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

## 15.3. 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.
- The **edk2-OVMF** packages is installed:

```
# yum 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 8. If you select a CD-ROM or DVD-ROM as the installation source when using any VM installation method available in RHEL 8, the installation will fail. For more information, see the Red Hat Knowledgebase.

- 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 interface. 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 rhel8.0 --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-8.0-
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

- Installing RHEL 8 on AMD64, Intel 64, and 64-bit ARM

## 15.4. LIMITING WHAT ACTIONS ARE AVAILABLE TO VIRTUAL MACHINE USERS

In some cases, actions that users of virtual machines (VMs) hosted on RHEL 8 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, uncomment the **access_drivers = [ "polkit" ]** line in the **/etc/libvirt/libvirtd.conf** file.

   ```
   # sed -i 's/#access_drivers = \[ "polkit" \]/access_drivers = \[ "polkit" \]/' /etc/libvirt/libvirtd.conf
   ```

3. Restart the **libvirtd** service.

   ```
   # systemctl restart libvirtd
   ```

### 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 8 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 instructions, see How to configure fine-grained control of Virtual Machines in Cockpit in the Red Hat Knowledgebase.

### Additional resources

- The **man polkit** command

- The **libvirt** upstream information about polkit access control policies

## 15.5. 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 8. These include:

**System and session connections**

To access all the available utilities for virtual machine management in RHEL 8, 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 8 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.

## 15.6. SELINUX BOOLEANS FOR VIRTUALIZATION

For fine-grained configuration of virtual machines security on a RHEL 8 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 8 and what they do when enabled:

**Table 15.1. 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. |
| 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. |

## 15.7. SETTING UP IBM SECURE EXECUTION ON IBM Z

When using IBM Z hardware to run a RHEL 8 host, you can improve the security of your virtual machines (VMs) by configuring IBM Secure Execution 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.

The following procedure describes how to convert an existing VM on an IBM Z host into a secured VM.

### 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**. To confirm this, use the following and replace **vm-name** with the name of your VM.

  ```
  # virsh dumpxml vm-name | grep "<cpu mode='host-model'/>"
  ```

  If the command generates any output, the VM's CPU mode is set correctly.
- You have obtained and verified the IBM Z host key document. For instructions to do so, 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.

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
crashkernel=auto
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 crashkernel=auto rd.lvm.lv=rhel/root rd.lvm.lv=rhel/swap
swiotlb=262144" > ~/secure-parameters
```

5. Generate an 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.

### 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 on starting a secure virtual server
- IBM documentation on **genprotimg**

- Configuring kernel command-line parameters

## 15.8. 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.

## 15.9. 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.
```

## 15.10. 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

- Ensure that standard hardware security is enabled. For more information, see Enabling standard hardware security on Windows virtual machines.

- Ensure 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**

# CHAPTER 16. 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 8, so that your hardware infrastructure resources can be used as efficiently as possible.

## 16.1. 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 8 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 adverse effects on other virtualization functions. For example, it can make migrating the modified VM more difficult.

## 16.2. 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 8 for virtualization, use the following profiles:

- For RHEL 8 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 8 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
```

### Additional resources

- Monitoring and managing system status and performance

## 16.3. 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.

To perform these actions, you can use the web console or the command-line interface.

### 16.3.1. Adding and removing virtual machine memory by using the web console

To improve the performance of a virtual machine (VM) or to free up the host resources it is using, you can use the web console to adjust amount of memory allocated to the VM.

#### Prerequisites

- The guest OS is running the memory balloon drivers. To verify this is the case:
  1. Ensure the VM's configuration includes the **memballoon** device:

     ```
     # virsh dumpxml testguest | grep memballoon
     <memballoon model='virtio'>
         </memballoon>
     ```

     If this commands displays any output and the model is not set to **none**, the **memballoon** device is present.

  2. Ensure the balloon drivers are running in the guest OS.
     - In Windows guests, the drivers are installed as a part of the **virtio-win** driver package. For instructions, see Installing KVM paravirtualized drivers for Windows virtual machines.
     - In Linux guests, the drivers are generally included by default and activate when the **memballoon** device is present.
- The web console VM plug-in is installed on your system.

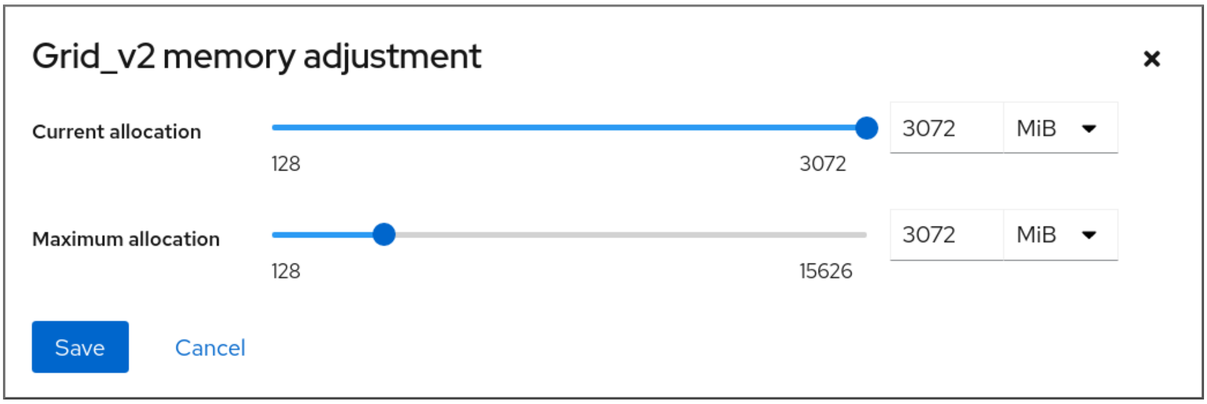
#### Procedure

1. **Optional:** Obtain the information about the maximum memory and currently used memory for a VM. This will serve as a baseline for your changes, and also for verification.

   ```
   # virsh dominfo testguest
   Max memory:     2097152 KiB
   Used memory:    2097152 KiB
   ```

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 **Memory** line in the Overview pane.
   The **Memory Adjustment** dialog appears.




4. Configure the virtual CPUs for the selected VM.

   - **Maximum allocation** - Sets the maximum amount of host memory that the VM can use for its processes. You can specify the maximum memory when creating the VM or increase it later. You can specify memory as multiples of MiB or GiB.
     Adjusting maximum memory allocation is only possible on a shut-off VM.

   - **Current allocation** - Sets the actual amount of memory allocated to the VM. This value can be less than the Maximum allocation but cannot exceed it. You can adjust the value to regulate the memory available to the VM for its processes. You can specify memory as multiples of MiB or GiB.
     If you do not specify this value, the default allocation is the **Maximum allocation** value.

5. Click **Save**.
   The memory allocation of the VM is adjusted.

#### Additional resources

- Adding and removing virtual machine memory by using the command-line interface

- Optimizing virtual machine CPU performance

### 16.3.2. Adding and removing virtual machine memory by using the command-line interface

To improve the performance of a virtual machine (VM) or to free up the host resources it is using, you can use the CLI to adjust amount of memory allocated to the VM.

#### Prerequisites

- The guest OS is running the memory balloon drivers. To verify this is the case:

  1. Ensure the VM's configuration includes the **memballoon** device:

```
# virsh dumpxml testguest | grep memballoon
<memballoon model='virtio'>
  </memballoon>
```

If this commands displays any output and the model is not set to **none**, the **memballoon** device is present.

2. Ensure the ballon drivers are running in the guest OS.
   - In Windows guests, the drivers are installed as a part of the **virtio-win** driver package. For instructions, see Installing KVM paravirtualized drivers for Windows virtual machines.
   - In Linux guests, the drivers are generally included by default and activate when the **memballoon** device is present.

### Procedure

1. **Optional:** Obtain the information about the maximum memory and currently used memory for a VM. This will serve as a baseline for your changes, and also for verification.

```
# virsh dominfo testguest
Max memory:     2097152 KiB
Used memory:    2097152 KiB
```

2. Adjust the maximum memory allocated to a VM. Increasing this value improves the performance potential of the VM, and reducing the value lowers the performance footprint the VM has on your host. Note that this change can only be performed on a shut-off VM, so adjusting a running VM requires a reboot to take effect.
For example, to change the maximum memory that the *testguest* VM can use to 4096 MiB:

```
# virt-xml testguest --edit --memory memory=4096,currentMemory=4096
Domain 'testguest' defined successfully.
Changes will take effect after the domain is fully powered off.
```

To increase the maximum memory of a running VM, you can attach a memory device to the VM. This is also referred to as **memory hot plug**. For details, see Attaching devices to virtual machines.

> **WARNING**
>
> Removing memory devices from a running VM (also referred as a memory hot unplug) is not supported, and highly discouraged by Red Hat.

3. **Optional:** You can also adjust the memory currently used by the VM, up to the maximum allocation. This regulates the memory load that the VM has on the host until the next reboot, without changing the maximum VM allocation.

```
# virsh setmem testguest --current 2048
```

#### Verification

1. Confirm that the memory used by the VM has been updated:

```
# virsh dominfo testguest
Max memory:     4194304 KiB
Used memory:    2097152 KiB
```

2. **Optional:** If you adjusted the current VM memory, you can obtain the memory balloon statistics of the VM to evaluate how effectively it regulates its memory use.

```
 # virsh domstats --balloon testguest
Domain: 'testguest'
  balloon.current=365624
  balloon.maximum=4194304
  balloon.swap_in=0
  balloon.swap_out=0
  balloon.major_fault=306
  balloon.minor_fault=156117
  balloon.unused=3834448
  balloon.available=4035008
  balloon.usable=3746340
  balloon.last-update=1587971682
  balloon.disk_caches=75444
  balloon.hugetlb_pgalloc=0
  balloon.hugetlb_pgfail=0
  balloon.rss=1005456
```

#### Additional resources

- Adding and removing virtual machine memory by using the web console
- Optimizing virtual machine CPU performance

### 16.3.3. Additional resources

- Attaching devices to virtual machines.

## 16.4. 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.

### 16.4.1. 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 *liftrul* VM to 500.

```
# virsh blkiotune liftbrul --device-weights /dev/sda, 500
```

## 16.4.2. 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 information

- 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 8 as a VM host, see Unsupported features in RHEL 8 virtualization .

### 16.4.3. Enabling multi-queue virtio-scsi

When using **virtio-scsi** storage devices in your virtual machines (VMs), the *multi-queue virtio-scsi* 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.

#### Procedure

- To enable multi-queue virtio-scsi support for a specific VM, add the following to the VM's XML configuration, where *N* is the total number of vCPU queues:

```
<controller type='scsi' index='0' model='virtio-scsi'>
  <driver queues='N' />
</controller>
```

## 16.5. 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
   ```

3. Deactivate 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 Sample vCPU performance tuning scenario.

### 16.5.1. Adding and removing virtual CPUs by using the command-line interface

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 8, 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:

   - 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

## 16.5.2. Managing virtual CPUs by using the web console

By using the RHEL 8 web console, you can review and configure virtual CPUs used by virtual machines (VMs) to which the web console is connected.

### Prerequisites

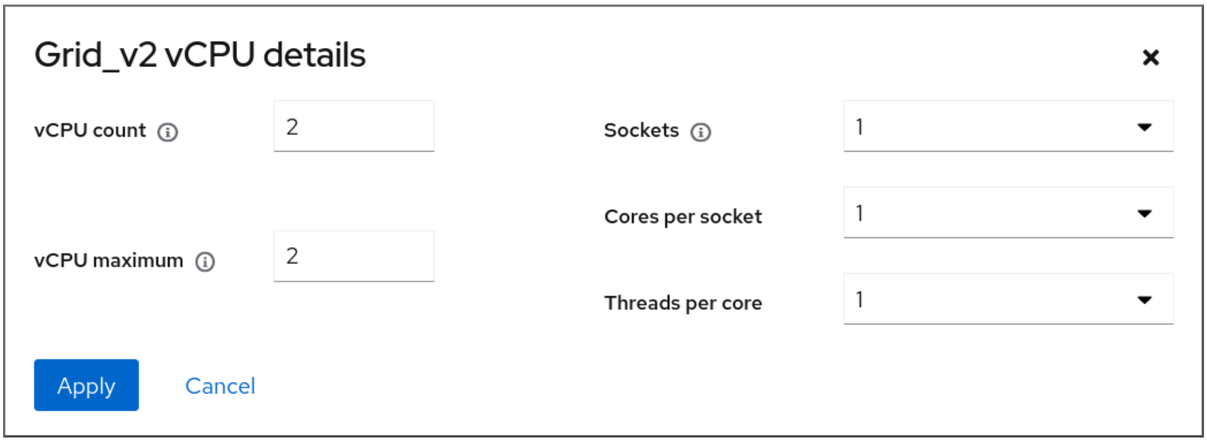
- The web console VM plug-in is installed on your system.

### Procedure

1. 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.

2. Click **edit** next to the number of vCPUs in the Overview pane.
The vCPU details dialog appears.




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 interface

## 16.5.3. 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 8 host.

### 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.

## Procedure

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.

### Automatic methods

- Set the VM's NUMA policy to **Preferred**. For example, to do so for the *testguest5* VM:

```
# virt-xml testguest5 --edit --vcpus placement=auto
# virt-xml testguest5 --edit --numatune mode=preferred
```

- Enable automatic NUMA balancing on the host:

```
# 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

1. Pin specific vCPU threads to a specific host CPU or range of CPUs. This is also possible on non-NUMA hosts and VMs, and is recommended as a safe method of vCPU performance improvement.
   For example, the following commands pin vCPU threads 0 to 5 of the *testguest6* VM to host CPUs 1, 3, 5, 7, 9, and 11, respectively:

```
# virsh vcpupin testguest6 0 1
# virsh vcpupin testguest6 1 3
# virsh vcpupin testguest6 2 5
# virsh vcpupin testguest6 3 7
# virsh vcpupin testguest6 4 9
# virsh vcpupin testguest6 5 11
```

Afterwards, you can verify whether this was successful:

```
# virsh vcpupin testguest6
VCPU   CPU Affinity
----------------------
0      1
1      3
2      5
3      7
4      9
5      11
```

2. 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. For example, the following commands pin the QEMU process thread of *testguest6* to CPUs 13 and 15, and verify this was successful:

```
# virsh emulatorpin testguest6 13,15
# virsh emulatorpin testguest6
emulator: CPU Affinity
----------------------------------
       *: 13,15
```

3. Finally, you can also 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. For example, the following commands set *testguest6* to use host NUMA nodes 3 to 5, and verify this was successful:

```
# virsh numatune testguest6 --nodeset 3-5
# virsh numatune testguest6
```

NOTE

For best performance results, it is recommended to use all of the manual tuning methods listed above

### Known issues

- NUMA tuning currently cannot be performed on IBM Z hosts

### Additional resources

- Sample vCPU performance tuning scenario
- View the current NUMA configuration of your system using the **numastat** utility

## 16.5.4. Sample vCPU performance tuning scenario

To obtain the best vCPU performance possible, Red Hat recommends by using manual **vcpupin**, **emulatorpin**, and **numatune** settings together, for example like in the following scenario.

### Starting scenario

- Your host has the following hardware specifics:
  - 2 NUMA nodes

- 3 CPU cores on each node
- 2 threads on each core

The output of **virsh nodeinfo** of such a machine would look similar to:

```
# virsh nodeinfo
CPU model:          x86_64
CPU(s):             12
CPU frequency:      3661 MHz
CPU socket(s):      2
Core(s) per socket: 3
Thread(s) per core: 2
NUMA cell(s):       2
Memory size:        31248692 KiB
```

- You intend to modify an existing VM to have 8 vCPUs, which means that it will not fit in a single NUMA node.
  Therefore, you should distribute 4 vCPUs on each NUMA node and make the vCPU topology resemble the host topology as closely as possible. This means that vCPUs that run as sibling threads of a given physical CPU should be pinned to host threads on the same core. For details, see the *Solution* below:

### Solution

1. Obtain the information about the host topology:

```
# virsh capabilities
```

The output should include a section that looks similar to the following:

```
<topology>
 <cells num="2">
  <cell id="0">
   <memory unit="KiB">15624346</memory>
   <pages unit="KiB" size="4">3906086</pages>
   <pages unit="KiB" size="2048">0</pages>
   <pages unit="KiB" size="1048576">0</pages>
   <distances>
    <sibling id="0" value="10" />
    <sibling id="1" value="21" />
   </distances>
   <cpus num="6">
    <cpu id="0" socket_id="0" core_id="0" siblings="0,3" />
    <cpu id="1" socket_id="0" core_id="1" siblings="1,4" />
    <cpu id="2" socket_id="0" core_id="2" siblings="2,5" />
    <cpu id="3" socket_id="0" core_id="0" siblings="0,3" />
    <cpu id="4" socket_id="0" core_id="1" siblings="1,4" />
    <cpu id="5" socket_id="0" core_id="2" siblings="2,5" />
   </cpus>
  </cell>
  <cell id="1">
   <memory unit="KiB">15624346</memory>
   <pages unit="KiB" size="4">3906086</pages>
   <pages unit="KiB" size="2048">0</pages>
```

```
      <pages unit="KiB" size="1048576">0</pages>
      <distances>
        <sibling id="0" value="21" />
        <sibling id="1" value="10" />
      </distances>
      <cpus num="6">
        <cpu id="6" socket_id="1" core_id="3" siblings="6,9" />
        <cpu id="7" socket_id="1" core_id="4" siblings="7,10" />
        <cpu id="8" socket_id="1" core_id="5" siblings="8,11" />
        <cpu id="9" socket_id="1" core_id="3" siblings="6,9" />
        <cpu id="10" socket_id="1" core_id="4" siblings="7,10" />
        <cpu id="11" socket_id="1" core_id="5" siblings="8,11" />
      </cpus>
    </cell>
  </cells>
</topology>
```

2. **Optional:** Test the performance of the VM by using the applicable tools and utilities.

3. Set up and mount 1 GiB huge pages on the host:

   a. Add the following line to the host's kernel command line:

   ```
   default_hugepagesz=1G hugepagesz=1G
   ```

   b. Create the **/etc/systemd/system/hugetlb-gigantic-pages.service** file with the following content:

   ```
   [Unit]
   Description=HugeTLB Gigantic Pages Reservation
   DefaultDependencies=no
   Before=dev-hugepages.mount
   ConditionPathExists=/sys/devices/system/node
   ConditionKernelCommandLine=hugepagesz=1G

   [Service]
   Type=oneshot
   RemainAfterExit=yes
   ExecStart=/etc/systemd/hugetlb-reserve-pages.sh

   [Install]
   WantedBy=sysinit.target
   ```

   c. Create the **/etc/systemd/hugetlb-reserve-pages.sh** file with the following content:

   ```
   #!/bin/sh

   nodes_path=/sys/devices/system/node/
   if [ ! -d $nodes_path ]; then
    echo "ERROR: $nodes_path does not exist"
    exit 1
   fi

   reserve_pages()
   {
   ```

```
 echo $1 > $nodes_path/$2/hugepages/hugepages-1048576kB/nr_hugepages
}

reserve_pages 4 node1
reserve_pages 4 node2
```

This reserves four 1GiB huge pages from *node1* and four 1GiB huge pages from *node2*.

d. Make the script created in the previous step executable:

```
# chmod +x /etc/systemd/hugetlb-reserve-pages.sh
```

e. Enable huge page reservation on boot:

```
# systemctl enable hugetlb-gigantic-pages
```

4. Use the **virsh edit** command to edit the XML configuration of the VM you wish to optimize, in this example *super-VM*:

```
# virsh edit super-vm
```

5. Adjust the XML configuration of the VM in the following way:

a. Set the VM to use 8 static vCPUs. Use the **<vcpu/>** element to do this.

b. Pin each of the vCPU threads to the corresponding host CPU threads that it mirrors in the topology. To do so, use the **<vcpupin/>** elements in the **<cputune>** section.
Note that, as shown by the **virsh capabilities** utility above, host CPU threads are not ordered sequentially in their respective cores. In addition, the vCPU threads should be pinned to the highest available set of host cores on the same NUMA node. For a table illustration, see the **Sample topology** section below.

The XML configuration for steps a. and b. can look similar to:

```
<cputune>
  <vcpupin vcpu='0' cpuset='1'/>
  <vcpupin vcpu='1' cpuset='4'/>
  <vcpupin vcpu='2' cpuset='2'/>
  <vcpupin vcpu='3' cpuset='5'/>
  <vcpupin vcpu='4' cpuset='7'/>
  <vcpupin vcpu='5' cpuset='10'/>
  <vcpupin vcpu='6' cpuset='8'/>
  <vcpupin vcpu='7' cpuset='11'/>
  <emulatorpin cpuset='6,9'/>
</cputune>
```

c. Set the VM to use 1 GiB huge pages:

```
<memoryBacking>
  <hugepages>
    <page size='1' unit='GiB'/>
  </hugepages>
</memoryBacking>
```

d. Configure the VM's NUMA nodes to use memory from the corresponding NUMA nodes on the host. To do so, use the **<memnode/>** elements in the **<numatune/>** section:

```
<numatune>
  <memory mode="preferred" nodeset="1"/>
  <memnode cellid="0" mode="strict" nodeset="0"/>
  <memnode cellid="1" mode="strict" nodeset="1"/>
</numatune>
```

e. Ensure the CPU mode is set to **host-passthrough**, and that the CPU uses cache in **passthrough** mode:

```
<cpu mode="host-passthrough">
  <topology sockets="2" cores="2" threads="2"/>
  <cache mode="passthrough"/>
```

### Verification

1. Confirm that the resulting XML configuration of the VM includes a section similar to the following:

```
[...]
  <memoryBacking>
    <hugepages>
      <page size='1' unit='GiB'/>
    </hugepages>
  </memoryBacking>
  <vcpu placement='static'>8</vcpu>
  <cputune>
    <vcpupin vcpu='0' cpuset='1'/>
    <vcpupin vcpu='1' cpuset='4'/>
    <vcpupin vcpu='2' cpuset='2'/>
    <vcpupin vcpu='3' cpuset='5'/>
    <vcpupin vcpu='4' cpuset='7'/>
    <vcpupin vcpu='5' cpuset='10'/>
    <vcpupin vcpu='6' cpuset='8'/>
    <vcpupin vcpu='7' cpuset='11'/>
    <emulatorpin cpuset='6,9'/>
  </cputune>
  <numatune>
    <memory mode="preferred" nodeset="1"/>
    <memnode cellid="0" mode="strict" nodeset="0"/>
    <memnode cellid="1" mode="strict" nodeset="1"/>
  </numatune>
  <cpu mode="host-passthrough">
    <topology sockets="2" cores="2" threads="2"/>
    <cache mode="passthrough"/>
    <numa>
      <cell id="0" cpus="0-3" memory="2" unit="GiB">
        <distances>
          <sibling id="0" value="10"/>
          <sibling id="1" value="21"/>
        </distances>
      </cell>
      <cell id="1" cpus="4-7" memory="2" unit="GiB">
```

```
        <distances>
          <sibling id="0" value="21"/>
          <sibling id="1" value="10"/>
        </distances>
      </cell>
    </numa>
  </cpu>
</domain>
```

2. **Optional:** Test the performance of the VM by using the applicable tools and utilities to evaluate the impact of the VM's optimization.

### Sample topology

- The following tables illustrate the connections between the vCPUs and the host CPUs they should be pinned to:

**Table 16.1. Host topology**

| **CPU threads** | 0 | 3 | 1 | 4 | 2 | 5 | 6 | 9 | 7 | 10 | 8 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cores** | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
| **Sockets** | 0 | | | | | | 1 | | | | | |
| **NUMA nodes** | 0 | | | | | | 1 | | | | | |

**Table 16.2. VM topology**

| **vCPU threads** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Cores** | 0 | | 1 | | 2 | | 3 | |
| **Sockets** | 0 | | | | 1 | | | |
| **NUMA nodes** | 0 | | | | 1 | | | |

**Table 16.3. Combined host and VM topology**

| **vCPU threads** | | | 0 | 1 | 2 | 3 | | | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Host CPU threads** | 0 | 3 | 1 | 4 | 2 | 5 | 6 | 9 | 7 | 10 | 8 | 11 |
| **Cores** | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | |
| **Sockets** | 0 | | | | | | 1 | | | | | |
| **NUMA nodes** | 0 | | | | | | 1 | | | | | |

In this scenario, there are 2 NUMA nodes and 8 vCPUs. Therefore, 4 vCPU threads should be pinned to each node.

In addition, Red Hat recommends leaving at least a single CPU thread available on each node for host system operations.

Because in this example, each NUMA node houses 3 cores, each with 2 host CPU threads, the set for node 0 translates as follows:

```
<vcpupin vcpu='0' cpuset='1'/>
<vcpupin vcpu='1' cpuset='4'/>
<vcpupin vcpu='2' cpuset='2'/>
<vcpupin vcpu='3' cpuset='5'/>
```

### 16.5.5. Deactivating kernel same-page merging

Although kernel same-page merging (KSM) improves memory density, it increases CPU utilization, and might adversely affect overall performance depending on the workload. In such cases, you can improve the virtual machine (VM) performance by deactivating KSM.

Depending on your requirements, you can either deactivate KSM for a single session or persistently.

#### Procedure

- To deactivate KSM for a single session, use the **systemctl** utility to stop **ksm** and **ksmtuned** services.

```
# systemctl stop ksm

# systemctl stop ksmtuned
```

- To deactivate 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
> ```
>
> After anonymous pages replace the KSM pages, the **khugepaged** kernel service will rebuild transparent hugepages on the VM's physical memory.

## 16.6. OPTIMIZING VIRTUAL MACHINE NETWORK PERFORMANCE

Due to the virtual nature of a VM's network interface card (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

## 16.7. 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 8 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 8 host. To do so:

1. On the host, install the *perf* package:

```
# yum 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.

### 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
```

## 16.8. ADDITIONAL RESOURCES

- Optimizing Windows virtual machines

# CHAPTER 17. INSTALLING AND MANAGING WINDOWS VIRTUAL MACHINES

To use Microsoft Windows as the guest operating system in your virtual machines (VMs) on a RHEL 8 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.

## 17.1. INSTALLING WINDOWS VIRTUAL MACHINES

You can create a fully-virtualized Windows machine on a RHEL 8 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 8 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 --tpm model=tpm-crb,backend.type=emulator,backend.version=2.0
```

- 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

## 17.2. OPTIMIZING WINDOWS VIRTUAL MACHINES

When using Microsoft Windows as a guest operating system in a virtual machine (VM) hosted in RHEL 8, 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.

### 17.2.1. 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 .

#### 17.2.1.1. 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)

#### 17.2.1.2. 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 8 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:

```
# yum install -y virtio-win
```

- If **virtio-win** is installed:

```
# yum 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.

### 17.2.1.3. 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.

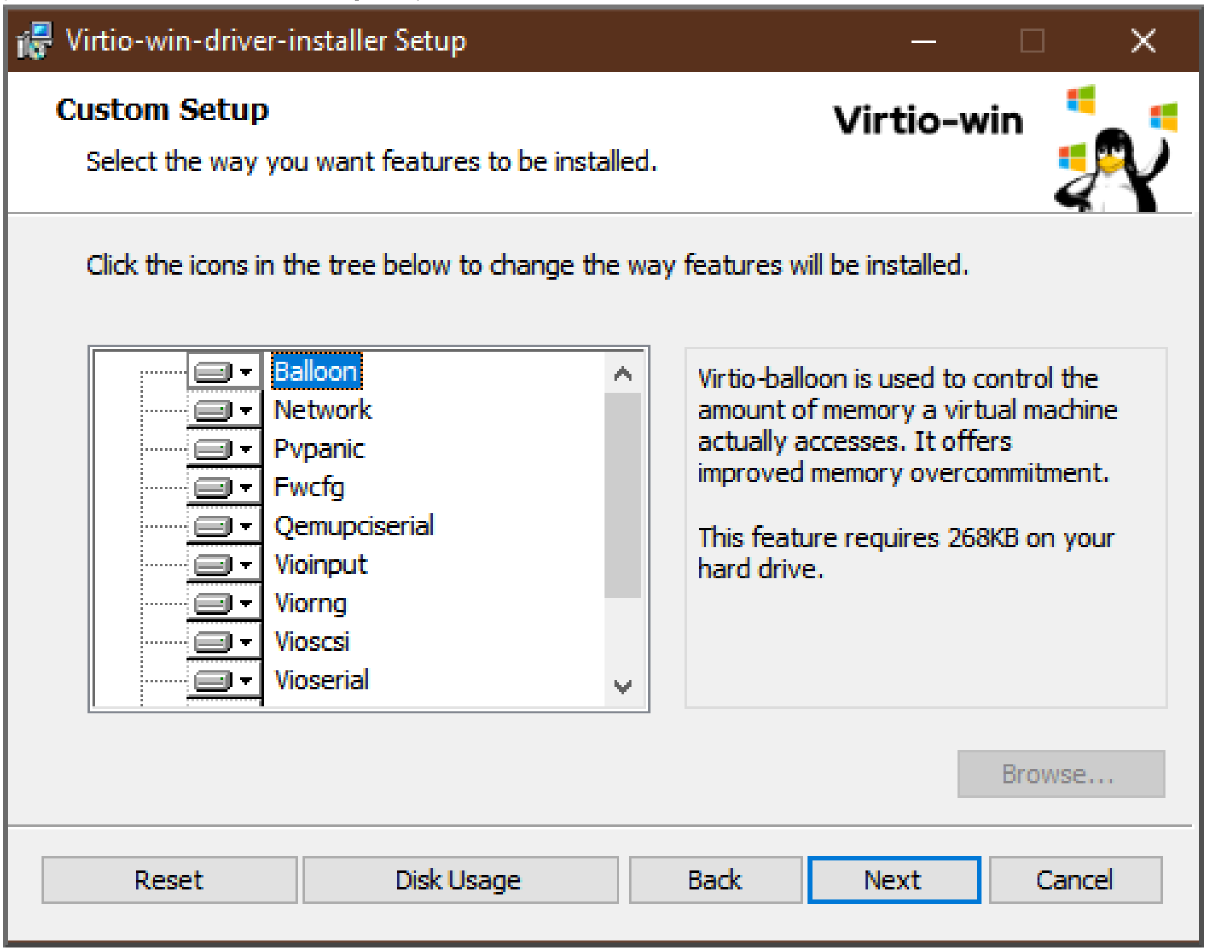
#### Prerequisites

- 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.




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.

#### 17.2.1.4. 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

### 17.2.1.5. Installing QEMU Guest Agent on Windows guests

To allow a host to perform various operations on a Windows virtual machine (VM), you can install the QEMU Guest Agent. 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.

This procedure provides instructions to install the guest agent by using the graphical interface. You can also use the Microsoft Windows Installer (MSI) command line interface.

#### 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.

#### 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**.

### 17.2.2. 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.

#### 17.2.2.1. 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 8 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'/>
       <vpindex state='on'/>
       <runtime state='on' />
       <synic state='on'/>
       <stimer state='on'>
         <direct state='on'/>
       </stimer>
       <frequencies 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'/>
  <vpindex state='on'/>
  <runtime state='on' />
  <synic state='on'/>
  <stimer state='on'>
    <direct state='on'/>
  </stimer>
  <frequencies state='on'/>
</hyperv>

<clock offset='localtime'>
  ...
  <timer name='hypervclock' present='yes'/>
</clock>
```

#### 17.2.2.2. 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 17.1. Configurable Hyper-V features**

| Enlightenment | Description | Values |
|---|---|---|
| crash | Provides MSRs to the VMs that can be used to store information and logs if a VM crashes. The information in available in the QEMU log.<br><br>**NOTE**<br><br>If hv_crash is enabled, Windows crash dumps are not created. | on, off |
| evmcs | Implements paravirtualized protocol between L0 (KVM) and L1 (Hyper-V) hypervisors, which enables faster L2 exits to the hypervisor.<br><br>**NOTE**<br><br>This feature is exclusive to Intel processors. | on, off |

| Enlightenment | Description | Values |
| --- | --- | --- |
| frequencies | Enables Hyper-V frequency Machine Specific Registers (MSRs). | on, off |
| ipi | Enables paravirtualized inter processor interrupts (IPI) support. | on, off |
| no-nonarch-coresharing | Notifies the guest OS that virtual processors will never share a physical core unless they are reported as sibling SMT threads. This information is required by Windows and Hyper-V guests to properly mitigate simultaneous multithreading (SMT) related CPU vulnerabilities. | on, off, auto |
| 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.<br>• 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,<br>• MSR-based 82 Hyper-V clock source (HV_X64_MSR_TIME_REF_COUNT, 0x40000020)<br>• 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<br>• Id value - string of up to 12 characters |
| vpindex | Enables virtual processor index. | on, off |

### 17.2.3. 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.

### 17.2.4. NetKVM driver parameters

The following table provides information about the configurable NetKVM driver logging parameters.

**Table 17.2. 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.<br>• The default value is 0 (errors only).<br>• 1-2 adds configuration messages.<br>• 3-4 adds packet flow information.<br>• 5-6 adds interrupt and DPC level trace information.<br>**NOTE**<br>High logging levels will slow down your virtual machine. |

The following table provides information about the configurable NetKVM driver initial parameters.

**Table 17.3. 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.<br><br>The default value is 1024.<br><br>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.<br><br>The default value is 1024.<br><br>Valid values are: 16, 32, 64, 128, 256, 512, 1024, 2048, and 4096. |
| Offload.Tx.Checksum | Specifies the TX checksum offloading capability.<br><br>In Red Hat Enterprise Linux 8, the valid values for this parameter are:<br><br>• All (the default) which enables IP, TCP, and UDP checksum offloading for both IPv4 and IPv6<br><br>• TCP/UDP(v4,v6) which enables TCP and UDP checksum offloading for both IPv4 and IPv6<br><br>• TCP/UDP(v4) which enables TCP and UDP checksum offloading for IPv4 only<br><br>• TCP(v4) which enables only TCP checksum offloading for IPv4 only |
| Offload.Rx.Checksum | Specifies the RX checksum offloading capability.<br><br>In Red Hat Enterprise Linux 8, the valid values for this parameter are:<br><br>• All (the default) which enables IP, TCP, and UDP checksum offloading for both IPv4 and IPv6<br><br>• TCP/UDP(v4,v6) which enables TCP and UDP checksum offloading for both IPv4 and IPv6<br><br>• TCP/UDP(v4) which enables TCP and UDP checksum offloading for IPv4 only<br><br>• TCP(v4) which enables only TCP checksum offloading for IPv4 only |

| Parameter | Description |
| --- | --- |
| Offload.Tx.LSO | Specifies the TX large segments offloading (LSO) capability.<br><br>In Red Hat Enterprise Linux 8, the valid values for this parameter are:<br><br>• Maximal (the default) which enables LSO offloading for both TCPv4 and TCPv6<br>• IPv4 which enables LSO offloading for TCPv4 only<br>• 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)<br><br>Minimum value (default) - **0**, meaning the driver never indicates low resources condition.<br><br>Maximum value - **100**, meaning the driver indicates low resources condition all the time. |

#### Additional resources

- INF enumeration keywords
- INF keywords that can be edited

### 17.2.5. 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.

## 17.3. 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.
```

## 17.4. 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

- Ensure that standard hardware security is enabled. For more information, see Enabling standard hardware security on Windows virtual machines.

- Ensure 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**.

## 17.5. NEXT STEPS

- To share files between your RHEL 8 host and its Windows VMs, you can use NFS.

# CHAPTER 18. CREATING NESTED VIRTUAL MACHINES

On RHEL 8 systems and later, it is possible to create nested virtual machines (VMs). This means that a RHEL 8 VM (also referred to as a **level 1**, or **L1**) that runs on a RHEL 8 physical host ( **level 0**, or **L0**) can act as a hypervisor and create its own VMs (**level 2** or **L2**).

In other words, an L0 host can run L1 virtual machines (VMs), and each of these L1 VMs can host their own L2 VMs. Note that, in such cases, both L0 and L1 hosts must be RHEL 8 systems, whereas the L2 guest can be any supported RHEL or Windows system.

> **WARNING**
>
> Red Hat currently provides nested virtualization only as a Technology Preview, and is therefore unsupported.

In addition, Red Hat does not recommend using nested virtualization in production user environments, due to various limitations in functionality . Instead, 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

It is also possible to create nested VMs on multiple architectures, such as Intel, AMD, IBM POWER9, and IBM Z. Note that on all these architectures, nesting VMs is a Technology Preview, and therefore not supported by Red Hat.

## 18.1. CREATING A NESTED VIRTUAL MACHINE ON INTEL

Follow the steps below to enable and configure nested virtualization on an Intel host.

> **WARNING**
>
> Nested virtualization is currently provided only as a Technology Preview on the Intel architecture, and is therefore unsupported.

### Prerequisites

- An L0 RHEL 8 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.

## 18.2. CREATING A NESTED VIRTUAL MACHINE ON AMD

Follow the steps below to enable and configure nested virtualization on an AMD host.

> **WARNING**
>
> Nested virtualization is currently provided only as a Technology Preview on the AMD64 architecture, and is therefore unsupported.

### Prerequisites

- An L0 RHEL 8 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.

## 18.3. CREATING A NESTED VIRTUAL MACHINE ON IBM Z

Follow the steps below to enable and configure nested virtualization on an IBM Z host.

> **WARNING**
>
> Nested virtualization is currently provided only as a Technology Preview on the IBM Z architecture, and is therefore unsupported.

### Prerequisites

- An L0 RHEL 8 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.

## 18.4. CREATING A NESTED VIRTUAL MACHINE ON IBM POWER9

Follow the steps below to enable and configure nested virtualization on an IBM POWER9 host.

> **WARNING**
>
> Nested virtualization is currently provided only as a Technology Preview on the IBM POWER9 architecture, and is therefore unsupported. In addition, creating nested virtual machines (VMs) is not possible on previous versions of IBM POWER systems, such as IBM POWER8.

**Prerequisites**

- An L0 RHEL 8 host is running an L1 VM. The L1 VM is using RHEL 8 as the guest operating system.
- Nested virtualization is enabled on the L0 host:

  ```
  # cat /sys/module/kvm_hv/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_hv
    ```

    iii. Activate the nesting feature:

    ```
    # modprobe kvm_hv 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_hv nested=1
    ```

### Procedure

1. To ensure that the L1 VM can create L2 VMs, add the **cap-nested-hv** parameter to the machine type of the L1 VM. To do so, use the **virsh edit** command to modify the L1 VM's XML configuration, and the following line to the **<features>** section:

   ```
   <nested-hv state='on'/>
   ```

2. Create an L2 VM within the L1 VM. To do this, follow the same procedure as when creating the L1 VM.
   To significantly improve the performance of L2 VMs, Red Hat recommends adding the`cap-nested-hv` parameter to the XML configurations of L2 VMs as well. For instructions, see the previous step.

### Additional information

- Note that **IBM POWER8** as the architecture for the L2 VM currently does not supported.

## 18.5. RESTRICTIONS AND LIMITATIONS FOR NESTED VIRTUALIZATION

Keep the following restrictions in mind when using nested virtualization.

> **WARNING**
>
> Red Hat currently does not support nested virtualization, and only provides nesting as a Technology Preview.

### Supported architectures

- The L0 host must be an Intel, AMD, IBM POWER9, or IBM Z system. Nested virtualization currently does not work on other architectures.

### Supported guest operating systems

- To create nested VMs, you must use the following guest operating systems (OSs):
  - On the **L0 host** - RHEL 8.2 and later
  - On the **L1 VMs** - RHEL 7.8 and later, or RHEL 8.2 and later

> **NOTE**
>
> This support does not apply to using virtualization offerings based on RHEL 7 and RHEL 8 in L1 VMs. These include:
>
> - Red Hat Virtualization
> - Red Hat OpenStack Platform
> - OpenShift Virtualization

- On the **L2 VMs** - you must use one of the following OSs:
  - RHEL 7.8 and later
  - RHEL 8.2 and later
  - Microsoft Windows Server 2016
  - Microsoft Windows Server 2019

- In addition, on IBM POWER9, nested virtualization currently only works under the following circumstances:
  - Both the L0 host and the L1 VM use RHEL 8
  - The L2 VM uses RHEL 8, or RHEL 7 with a **rhel-alt** kernel.
  - The L1 VM and L2 VM are not running in POWER8 compatibility mode.

**Hypervisor limitations**

- Currently, Red Hat supports nesting only on RHEL-KVM. When RHEL is used as the L0 hypervisor, you can use RHEL 8 or Windows for WSL 2 as the L1 hypervisor.
- When using an L1 RHEL 8 VM on a non-KVM L0 hypervisor, such as VMware ESXi or Amazon Web Services (AWS), creating L2 VMs in the RHEL 8 guest OS may work, but is not supported.

**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 may be unavailable for the L1 hypervisor.

For example, on IBM POWER 9 hardware, the External Interrupt Virtualization Engine (XIVE) does not work. However, L1 VMs can use the emulated XIVE interrupt controller to launch L2 VMs.

# CHAPTER 19. 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.

## 19.1. 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.

### 19.1.1. 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.

### 19.1.2. Enabling persistent settings for libvirt debug logs

You can configure libvirt debug logging to be automatically enabled whenever libvirt starts. By default, **libvirtd** is the only libvirt daemon in RHEL 8. To make persistent changes in the libvirt configuration, you must edit the **libvirtd.conf** file, located in the **/etc/libvirt** directory.

#### Procedure

1. Open the **libvirtd.conf** file in an editor.

2. Replace or set the filters according to your requirements.

   **Table 19.1. 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 19.1. 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 libvirtd.service
```

### 19.1.3. 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 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 19.2. 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 19.2. 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 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 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 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.

### 19.1.4. 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?

## 19.2. 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.

### 19.2.1. 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
- The **crash** Github repository

### 19.2.2. 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

- The **virsh dump --help** command
- The **virsh** man page
- Opening a Support Case

## 19.3. 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

- The **gstack** man page
- 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 What is an SOS Report and how to create one in Red Hat Enterprise Linux?
  - For information about attaching log files, see How to provide files to Red Hat Support?

# CHAPTER 20. FEATURE SUPPORT AND LIMITATIONS IN RHEL 8 VIRTUALIZATION

This document provides information about feature support and restrictions in Red Hat Enterprise Linux 8 (RHEL 8) virtualization.

## 20.1. HOW RHEL VIRTUALIZATION SUPPORT WORKS

A set of support limitations applies to virtualization in Red Hat Enterprise Linux 8 (RHEL 8). This means that when you use certain features or exceed a certain amount of allocated resources when using virtual machines in RHEL 8, Red Hat will not support these guests unless you have a specific subscription plan.

Features listed in Recommended features in RHEL 8 virtualization have been tested and certified by Red Hat to work with the KVM hypervisor on a RHEL 8 system. Therefore, they are fully supported and recommended for use in virtualization in RHEL 8.

Features listed in Unsupported features in RHEL 8 virtualization may work, but are not supported and not intended for use in RHEL 8. Therefore, Red Hat strongly recommends not using these features in RHEL 8 with KVM.

Resource allocation limits in RHEL 8 virtualization lists the maximum amount of specific resources supported on a KVM guest in RHEL 8. Guests that exceed these limits are not supported by Red Hat.

In addition, unless stated otherwise, all features and solutions used by the documentation for RHEL 8 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 Red Hat Virtualization (RHV), OpenShift Virtualization or Red Hat OpenStack Platform (RHOSP).

## 20.2. RECOMMENDED FEATURES IN RHEL 8 VIRTUALIZATION

The following features are recommended for use with the KVM hypervisor included with Red Hat Enterprise Linux 8 (RHEL 8):

### Host system architectures

RHEL 8 with KVM is only supported on the following host architectures:

- AMD64 and Intel 64
- IBM Z - IBM z13 systems and later
- IBM POWER8
- IBM POWER9

Any other hardware architectures are not supported for using RHEL 8 as a KVM virtualization host, and Red Hat highly discourages doing so. Notably, this includes the 64-bit ARM architecture (ARM 64).

### NOTE

RHEL 8 documentation primarily describes AMD64 and Intel 64 features and usage. For information about the specific of using RHEL 8 virtualization on different architectures, see:

- Getting started with virtualization on IBM POWER
- Getting started with virtualization on IBM Z

### Guest operating systems

Red Hat provides support with KVM virtual machines that use specific guest operating systems (OSs). For a detailed list of supported guest OSs, see the 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.

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 8.

- On **Intel 64 and AMD64** (x86_64): **pc-q35-rhel8.*Y*.0** → **--machine=q35**
- On **IBM Z** (s390x): **s390-ccw-virtio-rhel8.*Y*.0** → **--machine=s390-ccw-virtio**
- On **IBM POWER** (PPC), **pseries-rhel8.*Y*.0** → **--machine=pseries**

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 8 virtualization
- Resource allocation limits in RHEL 8 virtualization
- Supported hosts for virtual machine migration

## 20.3. UNSUPPORTED FEATURES IN RHEL 8 VIRTUALIZATION

The following features are not supported by the KVM hypervisor included with Red Hat Enterprise Linux 8 (RHEL 8):

> **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 RHV 4.2 and later, or RHOSP 13 and later, are described as such in the following paragraphs.

### Host system architectures

RHEL 8 with KVM is not supported on any host architectures that are not listed in Recommended features in RHEL 8 virtualization.

Notably, Red Hat does not support using systems with the 64-bit ARM architecture (ARM 64) for KVM virtualization on RHEL 8.

### Guest operating systems

KVM virtual machines (VMs) that use the following guest operating systems (OSs) are not supported on a RHEL 8 host:

- Microsoft Windows 8.1 and earlier
- Microsoft Windows Server 2008 R2 and earlier
- macOS
- Solaris for x86 systems
- Any OS released before 2009

For a list of guest OSs supported on RHEL hosts, Red Hat Virtualization (RHV), or 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 8 hypervisor (such as the **QEMU** emulator or the **libvirt** package).

To create VMs in containers, Red Hat recommends using the OpenShift Virtualization offering.

### The QEMU command line

QEMU is an essential component of the virtualization architecture in RHEL 8, but it is difficult to manage manually, and improper QEMU configurations may 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 **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.

### 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 8.

### Memory hot unplug

Removing a memory device attached to a running VM, also referred to as a memory hot unplug, is unsupported in RHEL 8.

### QEMU-side I/O throttling

By 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 8.

To set up I/O throttling in RHEL 8, use **virsh blkiotune**. This is also known as libvirt-side I/O throttling. For instructions, see Disk I/O throttling in virtual machines .

QEMU-side I/O throttling is also supported in RHOSP. For details, see 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

Migrating a disk image of a running VM between hosts is not supported in RHEL 8.

Other solutions:

- Storage live migration is supported in RHOSP, but with some limitations. For details, see Migrate a Volume .

### Live snapshots

Creating or loading a snapshot of a running VM, also referred to as a live snapshot, is not supported in RHEL 8.

In addition, note that non-live VM snapshots are deprecated in RHEL 8. Therefore, creating or loading a snapshot of a shut-down VM is supported, but Red Hat recommends not using it.

Other solutions:

- Live snapshots are supported in RHOSP. For details, see Importing virtual machines into the overcloud.

- Live snapshots are also supported on OpenShift Virtualization.

### vhost-user

RHEL 8 does not support the implementation of a user-space vHost interface.

Note that vhost-user is supported in RHOSP, but only for **virtio-net** interfaces. For details, see virtio-net implementation and vhost user ports.

### 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.

### S3-PR on a multipathed vDisk

SCSI3 persistent reservation (S3-PR) on a multipathed vDisk is not supported in RHEL 8. As a consequence, Windows Cluster is not supported in RHEL 8.

### virtio-crypto

Using the *virtio-crypto* device in RHEL 8 is not supported and its use is therefore highly discouraged.

Note that *virtio-crypto* devices are also not supported in any other virtualization solution provided by Red Hat.

### 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 8, and Red Hat highly discourages its use.

### net_failover

Using the **net_failover** driver to set up an automated network device failover mechanism is not supported in RHEL 8.

Note that **net_failover** is also currently not supported in any other virtualization solution provided by Red Hat.

### Multi-FD migration

Migrating VMs using multiple file descriptors (FDs), also known as multi-FD migration, is not supported in RHEL 8.

Note that multi-FD migrations are also currently not supported in any other virtualization solution provided by Red Hat.

### TPM passthrough

Assigning a physical Trusted Platform Module (TPM) device by using the passthrough back end to a VM is unsupported on RHEL 8 hosts. Instead, use the vTPM functionality, which uses the emulator back end and is fully supported.

### virtiofs

Sharing files between the host and its VMs by using the **virtiofs** file system is unsupported in RHEL 8.

Note, however, that using **virtiofs** is supported by RHEL 9. For more information, see Configuring and managing virtualization in RHEL 9.

### TCG

QEMU and libvirt include a dynamic translation mode by 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 by using Single-root I/O virtualization (SR-IOV) is not supported.

### Additional resources

- Recommended features in RHEL 8 virtualization
- Resource allocation limits in RHEL 8 virtualization

## 20.4. RESOURCE ALLOCATION LIMITS IN RHEL 8 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 8 (RHEL 8) host.

> **IMPORTANT**
>
> Many of these limitations do not apply to other virtualization solutions provided by Red Hat, such as Red Hat Virtualization (RHV), 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 8 host, see: Virtualization limits for Red Hat Enterprise Linux with KVM

### PCI devices per VM

RHEL 8 supports **64** PCI device slots per VM bus, and **8** PCI functions per device slot. This gives a theoretical maximum of 512 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 512 device addresses. However, some buses do not make all 512 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.

## 20.5. AN OVERVIEW OF VIRTUALIZATION FEATURES SUPPORT IN RHEL 8

The following tables provide comparative information about the support state of selected virtualization features in RHEL 8 across the supported system architectures.

**Table 20.1. Device hot plug and hot unplug**

| | Intel 64 and AMD64 | IBM Z | IBM POWER |
|---|---|---|---|
| **CPU hot plug** | Supported | Supported | Supported |
| **CPU hot unplug** | *UNSUPPORTED* | *UNSUPPORTED* | *UNSUPPORTED* |
| **Memory hot plug** | Supported | *UNSUPPORTED* | Supported |
| **Memory hot unplug** | *UNSUPPORTED* | *UNSUPPORTED* | *UNSUPPORTED* |
| **PCI hot plug** | Supported | Supported [a] | Supported |
| **PCI hot unplug** | Supported | Supported [b] | Supported |

[a] Requires using **virtio-*-ccw** devices instead of **virtio-*-pci**

[b] Requires using **virtio-*-ccw** devices instead of **virtio-*-pci**

**Table 20.2. Other selected features**

| | Intel 64 and AMD64 | IBM Z | IBM POWER |
|---|---|---|---|
| **NUMA tuning** | Supported | *UNSUPPORTED* | Supported |
| **SR-IOV devices** | Supported | *UNSUPPORTED* | Supported |
| **virt-v2v and p2v** | Supported | *UNSUPPORTED* | *UNSUPPORTED* |

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 8 virtualization.

### Additional sources

- For a complete list of unsupported features of virtual machines in RHEL 8, see Unsupported features in RHEL 8 virtualization.

- For details on the specifics for virtualization on the IBM Z architecture, see How virtualization on IBM Z differs from AMD64 and Intel 64.
- For details on the specifics for virtualization on the IBM POWER architecture, see How virtualization on IBM POWER differs from AMD64 and Intel 64.