OpenShift Container Platform 4.10

Virtualization

OpenShift Virtualization installation, usage, and release notes
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Abstract

This document provides information about how to use OpenShift Virtualization in OpenShift Container Platform.
Table of Contents

CHAPTER 1. ABOUT OPENSHIFT VIRTUALIZATION .................................................. 16
  1.1. WHAT YOU CAN DO WITH OPENSHIFT VIRTUALIZATION ............................ 16
      1.1.1. OpenShift Virtualization supported cluster version ............................. 16

CHAPTER 2. START HERE WITH OPENSHIFT VIRTUALIZATION ............................. 17
  2.1. CLUSTER ADMINISTRATOR ........................................................................... 17
  2.2. VIRTUALIZATION ADMINISTRATOR ............................................................. 17
  2.3. VIRTUAL MACHINE ADMINISTRATOR / DEVELOPER ................................. 17

CHAPTER 3. OPENSHIFT VIRTUALIZATION RELEASE NOTES ............................... 19
  3.1. ABOUT RED HAT OPENSHIFT VIRTUALIZATION .......................................... 19
      3.1.1. OpenShift Virtualization supported cluster version ............................. 19
      3.1.2. Supported guest operating systems ....................................................... 19
  3.2. MAKING OPEN SOURCE MORE INCLUSIVE ............................................... 19
  3.3. NEW AND CHANGED FEATURES .................................................................. 19
      3.3.1. Quick starts ............................................................................................ 19
      3.3.2. Installation ............................................................................................. 20
      3.3.3. Networking ............................................................................................ 20
      3.3.4. Storage .................................................................................................. 20
      3.3.5. Web console .......................................................................................... 20
  3.4. DEPRECATED AND REMOVED FEATURES .............................................. 20
      3.4.1. Deprecated features ................................................................................ 20
      3.4.2. Removed features ................................................................................... 21
  3.5. TECHNOLOGY PREVIEW FEATURES ......................................................... 21
  3.6. BUG FIXES .................................................................................................. 21
  3.7. KNOWN ISSUES ........................................................................................... 22

CHAPTER 4. INSTALLING ...................................................................................... 26
  4.1. CONFIGURING YOUR CLUSTER FOR OPENSHIFT VIRTUALIZATION ............ 26
      4.1.1. Changes in OpenShift Virtualization behavior on a single node cluster .... 28
      4.1.2. Additional hardware requirements for OpenShift Virtualization .......... 28
          4.1.2.1. Memory overhead ............................................................................. 28
          4.1.2.2. CPU overhead ............................................................................... 29
          4.1.2.3. Storage overhead ......................................................................... 29
          4.1.2.4. Example ......................................................................................... 29
  4.2. PLANNING YOUR ENVIRONMENT ACCORDING TO OPENSHIFT VIRTUALIZATION OBJECT MAXIMUMS ............................................................. 30
      4.2.1. About cluster limits for OpenShift Virtualization ................................. 30
      4.2.2. Additional resources .............................................................................. 30
  4.3. SPECIFYING NODES FOR OPENSHIFT VIRTUALIZATION COMPONENTS ........ 30
      4.3.1. About node placement for virtualization components ......................... 30
          4.3.1.1. How to apply node placement rules to virtualization components .... 30
          4.3.1.2. Node placement in the OLM Subscription object ........................... 31
          4.3.1.3. Node placement in the HyperConverged object ............................ 32
          4.3.1.4. Node placement in the HostPathProvisioner object ....................... 32
          4.3.1.5. Additional resources .................................................................... 32
      4.3.2. Example manifests .................................................................................. 33
          4.3.2.1. Operator Lifecycle Manager Subscription object ............................ 33
             4.3.2.1.1. Example: Node placement with nodeSelector in the OLM Subscription object .................................................................................. 33
             4.3.2.1.2. Example: Node placement with tolerations in the OLM Subscription object .............................................................................. 33
          4.3.2.2. HyperConverged object ................................................................... 34
             4.3.2.2.1. Example: Node placement with nodeSelector in the HyperConverged Cluster CR ................................................................. 34
4.3.2.2.2. Example: Node placement with affinity in the HyperConverged Cluster CR
4.3.2.2.3. Example: Node placement with tolerations in the HyperConverged Cluster CR
4.3.2.3. HostPathProvisioner object
4.3.2.3.1. Example: Node placement with nodeSelector in the HostPathProvisioner object

4.4. INSTALLING OPENSHIFT VIRTUALIZATION USING THE WEB CONSOLE
4.4.1. Installing the OpenShift Virtualization Operator
4.4.2. Next steps

4.5. INSTALLING OPENSHIFT VIRTUALIZATION USING THE CLI
4.5.1. Prerequisites
4.5.2. Subscribing to the OpenShift Virtualization catalog by using the CLI
4.5.3. Deploying the OpenShift Virtualization Operator by using the CLI
4.5.4. Next steps

4.6. ENABLING THE VIRTCTL CLIENT
4.6.1. Downloading and installing the virtctl client
4.6.1.1. Downloading the virtctl client
4.6.1.2. Installing the virtctl client
4.6.2. Additional setup options
4.6.2.1. Installing the virtctl client using the yum utility
4.6.2.2. Enabling OpenShift Virtualization repositories
4.6.3. Additional resources

4.7. UNINSTALLING OPENSHIFT VIRTUALIZATION USING THE WEB CONSOLE
4.7.1. Prerequisites
4.7.2. Deleting the OpenShift Virtualization Operator Deployment custom resource
4.7.3. Deleting the OpenShift Virtualization catalog subscription
4.7.4. Deleting a namespace using the web console

4.8. UNINSTALLING OPENSHIFT VIRTUALIZATION USING THE CLI
4.8.1. Prerequisites
4.8.2. Deleting OpenShift Virtualization

CHAPTER 5. UPDATING OPENSHIFT VIRTUALIZATION ......................................................... 45
5.1. ABOUT UPDATING OPENSHIFT VIRTUALIZATION ................................................. 45
5.2. CONFIGURING AUTOMATIC WORKLOAD UPDATES .............................. 45
5.2.1. About workload updates
5.2.2. Configuring workload update methods ......................................................... 46
5.3. APPROVING PENDING OPERATOR UPDATES ............................................. 48
5.3.1. Manually approving a pending Operator upgrade ........................................ 48
5.4. MONITORING UPDATE STATUS ................................................................. 48
5.4.1. Monitoring OpenShift Virtualization upgrade status ............................... 48
5.4.2. Viewing outdated OpenShift Virtualization workloads ......................... 49
5.5. ADDITIONAL RESOURCES ................................................................. 50

CHAPTER 6. ADDITIONAL SECURITY PRIVILEGES GRANTED FOR KUBEVIRT-CONTROLLER AND VIRT-LAUNCHER ................................................................. 51
6.1. EXTENDED SELINUX POLICIES FOR VIRT-LAUNCHER PODS ....................... 51
6.2. ADDITIONAL OPENSHIFT CONTAINER PLATFORM SECURITY CONTEXT CONSTRAINTS AND LINUX CAPABILITIES FOR THE KUBEVIRT-CONTROLLER SERVICE ACCOUNT 51
6.2.1. Additional SCCs granted to the kubevirt-controller service account ....... 51
6.2.2. Viewing the SCC and RBAC definitions for the kubevirt-controller .......... 52
6.3. ADDITIONAL RESOURCES ................................................................. 52

CHAPTER 7. USING THE CLI TOOLS ............................................................................. 53
7.1. PREREQUISITES ......................................................................................... 53
7.2. OPENSHIFT CONTAINER PLATFORM CLIENT COMMANDS ....................... 53
8.7.2.1. Connecting to the terminal
8.7.2.2. Connecting to the serial console
8.7.2.3. Connecting to the VNC console
8.7.2.4. Connecting to the RDP console
8.7.3. Accessing virtual machine consoles by using CLI commands
   8.7.3.1. Accessing a virtual machine instance via SSH
   8.7.3.2. Accessing a virtual machine via SSH with YAML configurations
   8.7.3.3. Accessing the serial console of a virtual machine instance
   8.7.3.4. Accessing the graphical console of a virtual machine instances with VNC
   8.7.3.5. Connecting to a Windows virtual machine with an RDP console
8.8. AUTOMATING WINDOWS INSTALLATION WITH SYSPREP
   8.8.1. Using a Windows DVD to create a VM disk image
   8.8.2. Using a disk image to install Windows
   8.8.3. Generalizing a Windows VM using sysprep
   8.8.4. Specializing a Windows VM
   8.8.5. Additional resources
8.9. TRIGGERING VIRTUAL MACHINE FAILOVER BY RESOLVING A FAILED NODE
   8.9.1. Prerequisites
   8.9.2. Deleting nodes from a bare metal cluster
   8.9.3. Verifying virtual machine failover
     8.9.3.1. Listing all virtual machine instances using the CLI
8.10. INSTALLING THE QEMU GUEST AGENT ON VIRTUAL MACHINES
   8.10.1. Installing QEMU guest agent on a Linux virtual machine
   8.10.2. Installing QEMU guest agent on a Windows virtual machine
     8.10.2.1. Installing VirtIO drivers on an existing Windows virtual machine
     8.10.2.2. Installing VirtIO drivers during Windows installation
8.11. VIEWING THE QEMU GUEST AGENT INFORMATION FOR VIRTUAL MACHINES
   8.11.1. Prerequisites
   8.11.2. About the QEMU guest agent information in the web console
   8.11.3. Viewing the QEMU guest agent information in the web console
8.12. MANAGING CONFIG MAPS, SECRETS, AND SERVICE ACCOUNTS IN VIRTUAL MACHINES
   8.12.1. Adding a secret, config map, or service account to a virtual machine
   8.12.2. Removing a secret, config map, or service account from a virtual machine
   8.12.3. Additional resources
8.13. INSTALLING VIRTIO DRIVER ON AN EXISTING WINDOWS VIRTUAL MACHINE
   8.13.1. About VirtIO drivers
   8.13.2. Supported VirtIO drivers for Microsoft Windows virtual machines
   8.13.3. Adding VirtIO drivers container disk to a virtual machine
   8.13.4. Installing VirtIO drivers on an existing Windows virtual machine
   8.13.5. Removing the VirtIO container disk from a virtual machine
8.14. INSTALLING VIRTIO DRIVER ON A NEW WINDOWS VIRTUAL MACHINE
   8.14.1. Prerequisites
   8.14.2. About VirtIO drivers
   8.14.3. Supported VirtIO drivers for Microsoft Windows virtual machines
   8.14.4. Adding VirtIO drivers container disk to a virtual machine
   8.14.5. Installing VirtIO drivers during Windows installation
   8.14.6. Removing the VirtIO container disk from a virtual machine
8.15. ADVANCED VIRTUAL MACHINE MANAGEMENT
   8.15.1. Specifying nodes for virtual machines
     8.15.1.1. About node placement for virtual machines
     8.15.1.2. Node placement examples
       8.15.1.2.1. Example: VM node placement with nodeSelector
       8.15.1.2.2. Example: VM node placement with pod affinity and pod anti-affinity
8.15.1.2.3. Example: VM node placement with node affinity
8.15.1.2.4. Example: VM node placement with tolerations
8.15.1.3. Additional resources
8.15.2. Configuring certificate rotation
  8.15.2.1. Configuring certificate rotation
  8.15.2.2. Troubleshooting certificate rotation parameters
8.15.3. Automating management tasks
  8.15.3.1. About Red Hat Ansible Automation
  8.15.3.2. Automating virtual machine creation
  8.15.3.3. Example: Ansible Playbook for creating virtual machines
8.15.4. Using EFI mode for virtual machines
  8.15.4.1. About EFI mode for virtual machines
  8.15.4.2. Booting virtual machines in EFI mode
8.15.5. Configuring PXE booting for virtual machines
  8.15.5.1. Prerequisites
  8.15.5.2. OpenShift Virtualization networking glossary
  8.15.5.3. PXE booting with a specified MAC address
  8.15.5.4. Template: Virtual machine configuration file for PXE booting
8.15.6. Managing guest memory
  8.15.6.1. Configuring guest memory overcommitment
  8.15.6.2. Disabling guest memory overhead accounting
8.15.7. Using huge pages with virtual machines
  8.15.7.1. Prerequisites
  8.15.7.2. What huge pages do
  8.15.7.3. Configuring huge pages for virtual machines
8.15.8. Enabling dedicated resources for virtual machines
  8.15.8.1. About dedicated resources
  8.15.8.2. Prerequisites
  8.15.8.3. Enabling dedicated resources for a virtual machine
8.15.9. Scheduling virtual machines
  8.15.9.1. Policy attributes
  8.15.9.2. Setting a policy attribute and CPU feature
  8.15.9.3. Scheduling virtual machines with the supported CPU model
  8.15.9.4. Scheduling virtual machines with the host model
8.15.10. Configuring PCI passthrough
  8.15.10.1. About preparing a host device for PCI passthrough
    8.15.10.1.1. Adding kernel arguments to enable the IOMMU driver
    8.15.10.1.2. Binding PCI devices to the VFIO driver
    8.15.10.1.3. Exposing PCI host devices in the cluster using the CLI
    8.15.10.1.4. Removing PCI host devices from the cluster using the CLI
    8.15.10.2. Configuring virtual machines for PCI passthrough
      8.15.10.2.1. Assigning a PCI device to a virtual machine
  8.15.10.3. Additional resources
8.15.11. Configuring vGPU passthrough
  8.15.11.1. Assigning vGPU passthrough to virtual machines
  8.15.11.2. Additional resources
8.15.12. Configuring mediated devices
  8.15.12.1. Prerequisites
  8.15.12.2. About using virtual GPUs with OpenShift Virtualization
    8.15.12.2.1. Configuration overview
    8.15.12.2.2. How vGPUs are assigned to nodes
    8.15.12.2.3. About changing and removing mediated devices
  8.15.12.3. Preparing hosts for mediated devices
8.17.3.4. Template: Data volume virtual machine configuration file
8.17.3.5. CDI supported operations matrix
8.17.4. Cloning a virtual machine disk into a new block storage data volume
  8.17.4.1. Prerequisites
  8.17.4.2. About data volumes
  8.17.4.3. About block persistent volumes
  8.17.4.4. Creating a local block persistent volume
  8.17.4.5. Cloning the persistent volume claim of a virtual machine disk into a new data volume
  8.17.4.6. CDI supported operations matrix
8.18. VIRTUAL MACHINE NETWORKING
  8.18.1. Using the default pod network for virtual machines
    8.18.1.1. Configuring masquerade mode from the command line
    8.18.1.2. Configuring masquerade mode with dual-stack (IPv4 and IPv6)
    8.18.1.3. Selecting binding method
      8.18.1.3.1. Networking fields
    8.18.1.4. Virtual machine configuration examples for the default network
      8.18.1.4.1. Template: Virtual machine configuration file
      8.18.1.4.2. Template: Windows virtual machine configuration file
    8.18.1.5. Creating a service from a virtual machine
  8.18.2. Attaching a virtual machine to multiple networks
    8.18.2.1. OpenShift Virtualization networking glossary
    8.18.2.2. Configuring a Linux bridge
      8.18.2.2.1. Creating a Linux bridge using a node network configuration policy
      8.18.2.2.3. Creating a network attachment definition
        8.18.2.2.3.1. Creating a Linux bridge network attachment definition in the web console
        8.18.2.2.3.2. Creating a Linux bridge network attachment definition in the CLI
      8.18.2.2.4. Attaching the virtual machine to the additional network
        8.18.2.2.4.1. Creating a NIC for a virtual machine in the web console
        8.18.2.2.4.2. Networking fields
        8.18.2.2.4.3. Attaching a virtual machine to a secondary network in the CLI
    8.18.2.5. Additional resources
  8.18.3. Configuring IP addresses for virtual machines
    8.18.3.1. Configuring an IP address for a new virtual machine using cloud-init
  8.18.4. Configuring an SR-IOV network device for virtual machines
    8.18.4.1. Prerequisites
    8.18.4.2. Automated discovery of SR-IOV network devices
      8.18.4.2.1. Example SrovNetworkNodeState object
    8.18.4.3. Configuring SR-IOV network devices
    8.18.4.4. Next steps
  8.18.5. Connecting virtual machines to a service mesh
    8.18.5.1. Prerequisites
    8.18.5.2. Configuring a virtual machine for the service mesh
  8.18.6. Defining an SR-IOV network
    8.18.6.1. Prerequisites
    8.18.6.2. Configuring SR-IOV additional network
    8.18.6.3. Next steps
  8.18.7. Attaching a virtual machine to an SR-IOV network
    8.18.7.1. Prerequisites
    8.18.7.2. Attaching a virtual machine to an SR-IOV network
  8.18.8. Viewing the IP address of NICs on a virtual machine
    8.18.8.1. Prerequisites
    8.18.8.2. Viewing the IP address of a virtual machine interface in the CLI
8.18.8.3. Viewing the IP address of a virtual machine interface in the web console
8.18.9. Using a MAC address pool for virtual machines
8.18.9.1. About KubeMacPool
8.18.9.2. Disabling a MAC address pool for a namespace in the CLI
8.18.9.3. Re-enabling a MAC address pool for a namespace in the CLI
8.19. VIRTUAL MACHINE DISKS
8.19.1. Storage features
  8.19.1.1. OpenShift Virtualization storage feature matrix
8.19.2. Configuring local storage for virtual machines
  8.19.2.1. About the hostpath provisioner (HPP)
  8.19.2.2. Create the HPP custom resource with a storage pool
  8.19.2.3. Creating a storage class
    8.19.2.3.1. Creating a storage class for the CSI driver with the storagePools stanza
    8.19.2.3.2. Creating a storage class for the legacy hostpath provisioner
  8.19.2.4. Creating a storage pool using a pvcTemplate specification in a host path provisioner (HPP) custom resource.
8.19.3. Creating data volumes
  8.19.3.1. Creating data volumes using the storage API
  8.19.3.2. Creating data volumes using the PVC API
  8.19.3.3. Customizing the storage profile
    8.19.3.3.1. Setting a default cloning strategy using a storage profile
  8.19.3.4. Additional resources
8.19.4. Reserving PVC space for file system overhead
  8.19.4.1. How file system overhead affects space for virtual machine disks
  8.19.4.2. Overriding the default file system overhead value
8.19.5. Configuring CDI to work with namespaces that have a compute resource quota
  8.19.5.1. About CPU and memory quotas in a namespace
  8.19.5.2. Overriding CPU and memory defaults
  8.19.5.3. Additional resources
8.19.6. Managing data volume annotations
  8.19.6.1. Example: Data volume annotations
8.19.7. Using preallocation for data volumes
  8.19.7.1. About preallocation
  8.19.7.2. Enabling preallocation for a data volume
8.19.8. Uploading local disk images by using the web console
  8.19.8.1. Prerequisites
  8.19.8.2. CDI supported operations matrix
  8.19.8.3. Uploading an image file using the web console
  8.19.8.4. Additional resources
8.19.9. Uploading local disk images by using the virtctl tool
  8.19.9.1. Prerequisites
  8.19.9.2. About data volumes
  8.19.9.3. Creating an upload data volume
  8.19.9.4. Uploading a local disk image to a data volume
  8.19.9.5. CDI supported operations matrix
  8.19.9.6. Additional resources
8.19.10. Uploading a local disk image to a block storage data volume
  8.19.10.1. Prerequisites
  8.19.10.2. About data volumes
  8.19.10.3. About block persistent volumes
  8.19.10.4. Creating a local block persistent volume
  8.19.10.5. Creating an upload data volume
  8.19.10.6. Uploading a local disk image to a data volume
8.19.10.7. CDI supported operations matrix
8.19.10.8. Additional resources
8.19.11. Managing virtual machine snapshots
  8.19.11.1. About virtual machine snapshots
    8.19.11.1.1. Virtual machine snapshot controller and custom resource definitions (CRDs)
  8.19.11.2. Installing QEMU guest agent on a Linux virtual machine
  8.19.11.3. Installing QEMU guest agent on a Windows virtual machine
    8.19.11.3.1. Installing VirtIO drivers on an existing Windows virtual machine
    8.19.11.3.2. Installing VirtIO drivers during Windows installation
  8.19.11.4. Creating a virtual machine snapshot in the web console
  8.19.11.5. Creating an virtual machine snapshot in the CLI
  8.19.11.6. Verifying online snapshot creation with snapshot indications
  8.19.11.7. Restoring a virtual machine from a snapshot in the web console
  8.19.11.8. Restoring a virtual machine from a snapshot in the CLI
  8.19.11.9. Deleting a virtual machine snapshot in the web console
  8.19.11.10. Deleting a virtual machine snapshot in the CLI
  8.19.11.11. Additional resources
  8.19.12. Moving a local virtual machine disk to a different node
    8.19.12.1. Cloning a local volume to another node
  8.19.13. Expanding virtual storage by adding blank disk images
    8.19.13.1. About data volumes
    8.19.13.2. Creating a blank disk image with data volumes
    8.19.13.3. Template: Data volume configuration file for blank disk images
    8.19.13.4. Additional resources
    8.19.14.2. Cloning a data volume
    8.19.14.3. Additional resources
  8.19.15. Creating and using boot sources
    8.19.15.1. About virtual machines and boot sources
    8.19.15.2. Importing a Red Hat Enterprise Linux image as a boot source
    8.19.15.3. Adding a boot source for a virtual machine template
    8.19.15.4. Creating a virtual machine from a template with an attached boot source
    8.19.15.5. Creating a custom boot source
    8.19.15.6. Additional resources
  8.19.16. Hot-plugging virtual disks
    8.19.16.1. Hot-plugging a virtual disk using the CLI
    8.19.16.2. Hot-unplugging a virtual disk using the CLI
    8.19.16.3. Hot-plugging a virtual disk using the web console
    8.19.16.4. Hot-unplugging a virtual disk using the web console
  8.19.17. Using container disks with virtual machines
    8.19.17.1. About container disks
      8.19.17.1.1. Importing a container disk into a PVC by using a data volume
      8.19.17.1.2. Attaching a container disk to a virtual machine as a containerDisk volume
      8.19.17.2. Preparing a container disk for virtual machines
    8.19.17.3. Disabling TLS for a container registry to use as insecure registry
    8.19.17.4. Next steps
  8.19.18. Preparing CDI scratch space
    8.19.18.1. About data volumes
    8.19.18.2. About scratch space
      Manual provisioning
    8.19.18.3. CDI operations that require scratch space
    8.19.18.4. Defining a storage class
8.19.18.5. CDI supported operations matrix
8.19.18.6. Additional resources
8.19.19. Re-using persistent volumes
8.19.19.1. About reclaiming statically provisioned persistent volumes
8.19.19.2. Reclaiming statically provisioned persistent volumes
8.19.20. Expanding a virtual machine disk
8.19.20.1. Enlarging a virtual machine disk
8.19.20.2. Additional resources
8.19.21. Deleting data volumes
8.19.21.1. About data volumes
8.19.21.2. Listing all data volumes
8.19.21.3. Deleting a data volume

CHAPTER 9. VIRTUAL MACHINE TEMPLATES ........................................... 255

9.1. CREATING VIRTUAL MACHINE TEMPLATES .................................. 255
  9.1.1. About virtual machine templates
  9.1.2. About virtual machines and boot sources
  9.1.3. Adding a boot source for a virtual machine template
    9.1.3.1. Virtual machine template fields for adding a boot source
  9.1.4. Marking virtual machine templates as favorites
  9.1.5. Filtering the list of virtual machine templates by providers
  9.1.6. Creating a virtual machine template with the wizard in the web console
  9.1.7. Virtual machine template wizard fields
    9.1.7.1. Virtual machine template wizard fields
    9.1.7.2. Networking fields
    9.1.7.3. Storage fields
      Advanced storage settings
    9.1.7.4. Cloud-init fields
  9.1.8. Additional resources

9.2. EDITING VIRTUAL MACHINE TEMPLATES ...................................... 265
  9.2.1. Editing a virtual machine template in the web console
  9.2.2. Editing virtual machine template YAML configuration in the web console
  9.2.3. Adding a virtual disk to a virtual machine template
  9.2.4. Adding a network interface to a virtual machine template
  9.2.5. Editing CD-ROMs for Templates

9.3. ENABLING DEDICATED RESOURCES FOR VIRTUAL MACHINE TEMPLATES 268
  9.3.1. About dedicated resources
  9.3.2. Prerequisites
  9.3.3. Enabling dedicated resources for a virtual machine template

9.4. DEPLOYING A VIRTUAL MACHINE TEMPLATE TO A CUSTOM NAMESPACE 268
  9.4.1. Creating a custom namespace for templates
  9.4.2. Adding templates to a custom namespace
    9.4.2.1. Deleting templates from a custom namespace
    9.4.2.2. Additional resources

9.5. DELETING A VIRTUAL MACHINE TEMPLATE .................................... 270
  9.5.1. Deleting a virtual machine template in the web console

CHAPTER 10. LIVE MIGRATION .......................................................... 272

10.1. VIRTUAL MACHINE LIVE MIGRATION ......................................... 272
  10.1.1. About live migration
  10.1.2. Updating access mode for live migration

10.2. LIVE MIGRATION LIMITS AND TIMEOUTS .................................... 272
  10.2.1. Configuring live migration limits and timeouts
10.2.2. Cluster-wide live migration limits and timeouts
10.3. MIGRATING A VIRTUAL MACHINE INSTANCE TO ANOTHER NODE
  10.3.1. Initiating live migration of a virtual machine instance in the web console
  10.3.2. Initiating live migration of a virtual machine instance in the CLI
10.4. MIGRATING A VIRTUAL MACHINE OVER A DEDICATED SECONDARY NETWORK
  10.4.1. Configuring a dedicated secondary network for virtual machine live migration
  10.4.2. Additional resources
10.5. MONITORING LIVE MIGRATION OF A VIRTUAL MACHINE INSTANCE
  10.5.1. Monitoring live migration of a virtual machine instance in the web console
  10.5.2. Monitoring live migration of a virtual machine instance in the CLI
10.6. CANCELLING THE LIVE MIGRATION OF A VIRTUAL MACHINE INSTANCE
  10.6.1. Cancelling live migration of a virtual machine instance in the web console
  10.6.2. Cancelling live migration of a virtual machine instance in the CLI
10.7. CONFIGURING VIRTUAL MACHINE EVICTION STRATEGY
  10.7.1. Configuring custom virtual machines with the LiveMigration eviction strategy

CHAPTER 11. NODE MAINTENANCE ......................................................... 280
  11.1. ABOUT NODE MAINTENANCE ........................................... 280
     11.1.1. About node maintenance mode .................................. 280
     11.1.2. Maintaining bare metal nodes ................................... 280
  11.2. SETTING A NODE TO MAINTENANCE MODE .............................................. 281
     11.2.1. Setting a node to maintenance mode in the web console .......... 281
     11.2.2. Setting a node to maintenance mode in the CLI .................. 281
     11.2.3. Setting a node to maintenance mode with a NodeMaintenance custom resource ....... 282
     11.2.3.1. Checking status of current NodeMaintenance CR tasks ......... 283
  11.3. RESUMING A NODE FROM MAINTENANCE MODE ..................................... 284
     11.3.1. Resuming a node from maintenance mode in the web console .... 284
     11.3.2. Resuming a node from maintenance mode in the CLI ............. 284
     11.3.3. Resuming a node from maintenance mode that was initiated with a NodeMaintenance CR .... 284
  11.4. AUTOMATIC RENEWAL OF TLS CERTIFICATES .................................... 285
     11.4.1. TLS certificates automatic renewal schedules ..................... 285
  11.5. MANAGING NODE LABELING FOR OBSOLETE CPU MODELS .......... 285
     11.5.1. About node labeling for obsolete CPU models ................. 285
     11.5.2. About node labeling for CPU features .......................... 286
     11.5.3. Configuring obsolete CPU models .............................. 288
  11.6. PREVENTING NODE RECONCILIATION ................................................. 289
     11.6.1. Using skip-node annotation ...................................... 289
     11.6.2. Additional resources ............................................. 289

CHAPTER 12. NODE NETWORKING .......................................................... 290
  12.1. OBSERVING NODE NETWORK STATE .......................................... 290
     12.1.1. About nmstate .................................................... 290
     12.1.2. Viewing the network state of a node ............................ 290
  12.2. UPDATING NODE NETWORK CONFIGURATION .................................. 291
     12.2.1. About nmstate .................................................... 291
     12.2.2. Creating an interface on nodes .................................. 292
     Additional resources ...................................................... 293
     12.2.3. Confirming node network policy updates on nodes ............... 293
     12.2.4. Removing an interface from nodes ............................... 294
     12.2.5. Example policy configurations for different interfaces ........... 295
     12.2.5.1. Example: Linux bridge interface node network configuration policy .... 295
     12.2.5.2. Example: VLAN interface node network configuration policy .... 296
     12.2.5.3. Example: Bond interface node network configuration policy .... 297
12.2.5.4. Example: Ethernet interface node network configuration policy
12.2.5.5. Example: Multiple interfaces in the same node network configuration policy
12.2.6. Capturing the static IP of a NIC attached to a bridge
  12.2.6.1. Example: Linux bridge interface node network configuration policy to inherit static IP address from the NIC attached to the bridge
12.2.7. Examples: IP management
  12.2.7.1. Static
  12.2.7.2. No IP address
  12.2.7.3. Dynamic host configuration
  12.2.7.4. DNS
  12.2.7.5. Static routing
12.2.8. Capturing the static IP of a NIC attached to a bridge
12.2.9. Examples: IP management
  12.2.9.1. Static
  12.2.9.2. No IP address
  12.2.9.3. Dynamic host configuration
  12.2.9.4. DNS
  12.2.9.5. Static routing

12.3. TROUBLESHOOTING NODE NETWORK CONFIGURATION
12.3.1. Troubleshooting an incorrect node network configuration policy configuration

CHAPTER 13. LOGGING, EVENTS, AND MONITORING

13.1. REVIEWING VIRTUALIZATION OVERVIEW
  13.1.1. Prerequisites
  13.1.2. Resources monitored actively in the Virtualization Overview page
  13.1.3. Resources monitored for top consumption
  13.1.4. Reviewing top consumers for projects, virtual machines, and nodes
  13.1.5. Additional resources
13.2. VIEWING VIRTUAL MACHINE LOGS
  13.2.1. About virtual machine logs
  13.2.2. Viewing virtual machine logs in the CLI
  13.2.3. Viewing virtual machine logs in the web console
13.3. VIEWING EVENTS
  13.3.1. About virtual machine events
  13.3.2. Viewing the events for a virtual machine in the web console
  13.3.3. Viewing namespace events in the CLI
  13.3.4. Viewing resource events in the CLI
13.4. DIAGNOSING DATA VOLUMES USING EVENTS AND CONDITIONS
  13.4.1. About conditions and events
  13.4.2. Analyzing data volumes using conditions and events
13.5. VIEWING INFORMATION ABOUT VIRTUAL MACHINE WORKLOADS
  13.5.1. About the Virtual Machines dashboard
13.6. MONITORING VIRTUAL MACHINE HEALTH
  13.6.1. About readiness and liveness probes
  13.6.2. Defining an HTTP readiness probe
  13.6.3. Defining a TCP readiness probe
  13.6.4. Defining an HTTP liveness probe
  13.6.5. Template: Virtual machine configuration file for defining health checks
  13.6.6. Additional resources
13.7. USING THE OPENSHIFT CONTAINER PLATFORM DASHBOARD TO GET CLUSTER INFORMATION
  13.7.1. About the OpenShift Container Platform dashboards page
13.8. REVIEWING RESOURCE USAGE BY VIRTUAL MACHINES
  13.8.1. About reviewing top consumers
  13.8.2. Reviewing top consumers
  13.8.3. Additional resources
13.9. OPENSHIFT CONTAINER PLATFORM CLUSTER MONITORING, LOGGING, AND TELEMETRY
  13.9.1. About OpenShift Container Platform monitoring
  13.9.2. About logging subsystem components
  13.9.3. About Telemetry
    13.9.3.1. Information collected by Telemetry
14.2.1. Installing the OADP Operator
14.2.2. About backup and snapshot locations and their secrets
  Backup locations
  Snapshot locations
  Secrets
  14.2.2.1. Creating a default Secret
  14.2.2.2. Creating secrets for different credentials
14.2.3. Configuring the Data Protection Application
  14.2.3.1. Setting Velero CPU and memory resource allocations
  14.2.3.2. Enabling self-signed CA certificates
14.2.4. Installing the Data Protection Application
  14.2.4.1. Enabling CSI in the DataProtectionApplication CR
14.2.5. Uninstalling OADP
14.3. BACKING UP VIRTUAL MACHINES
  14.3.1. Creating a Backup CR
    14.3.1.1. Backing up persistent volumes with CSI snapshots
    14.3.1.2. Backing up applications with Restic
    14.3.1.3. Creating backup hooks
  14.3.2. Scheduling backups
  14.3.3. Additional resources
14.4. RESTORING VIRTUAL MACHINES
  14.4.1. Creating a Restore CR
    14.4.1.1. Creating restore hooks
CHAPTER 1. ABOUT OPENSHIFT VIRTUALIZATION

Learn about OpenShift Virtualization’s capabilities and support scope.

1.1. WHAT YOU CAN DO WITH OPENSHIFT VIRTUALIZATION

OpenShift Virtualization is an add-on to OpenShift Container Platform that allows you to run and manage virtual machine workloads alongside container workloads.

OpenShift Virtualization adds new objects into your OpenShift Container Platform cluster by using Kubernetes custom resources to enable virtualization tasks. These tasks include:

- Creating and managing Linux and Windows virtual machines
- Connecting to virtual machines through a variety of consoles and CLI tools
- Importing and cloning existing virtual machines
- Managing network interface controllers and storage disks attached to virtual machines
- Live migrating virtual machines between nodes

An enhanced web console provides a graphical portal to manage these virtualized resources alongside the OpenShift Container Platform cluster containers and infrastructure.

OpenShift Virtualization is designed and tested to work well with Red Hat OpenShift Data Foundation features.

You can use OpenShift Virtualization with the OVN-Kubernetes, OpenShift SDN, or one of the other certified default Container Network Interface (CNI) network providers listed in Certified OpenShift CNI Plug-ins.

1.1.1. OpenShift Virtualization supported cluster version

OpenShift Virtualization 4.10 is supported for use on OpenShift Container Platform 4.10 clusters. To use the latest z-stream release of OpenShift Virtualization, you must first upgrade to the latest version of OpenShift Container Platform.
## CHAPTER 2. START HERE WITH OPENSHIFT VIRTUALIZATION

Use the following tables to find content to help you learn about and use OpenShift Virtualization.

### 2.1. CLUSTER ADMINISTRATOR

<table>
<thead>
<tr>
<th>Learn</th>
<th>Plan</th>
<th>Deploy</th>
<th>Additional resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn about OpenShift Virtualization</td>
<td>Configuring your cluster for OpenShift Virtualization</td>
<td>Updating your node network configuration</td>
<td>Getting Support</td>
</tr>
<tr>
<td>Learn more about OpenShift Container Platform</td>
<td>Plan storage for virtual machine disks</td>
<td>Configuring CSI volumes</td>
<td></td>
</tr>
<tr>
<td>Learn about virtual machine live migration</td>
<td></td>
<td>Installing OpenShift Virtualization using the OpenShift Virtualization console or CLI</td>
<td></td>
</tr>
<tr>
<td>Learn about node maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.2. VIRTUALIZATION ADMINISTRATOR

<table>
<thead>
<tr>
<th>Learn</th>
<th>Deploy</th>
<th>Manage</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn about OpenShift Virtualization</td>
<td>Connecting virtual machines to the default pod network for virtual machines and multiple networks</td>
<td>Enabling the <code>virtctl</code> client</td>
<td>Importing virtual machines with the Migration Toolkit for containers</td>
</tr>
<tr>
<td>Learn about storage features for virtual machine disks</td>
<td>Customizing the storage profile</td>
<td>Using the CLI tools</td>
<td>Using live migration</td>
</tr>
<tr>
<td></td>
<td>Creating boot sources and attaching them to templates</td>
<td>Viewing logs and events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Updating boot source templates</td>
<td>Monitoring virtual machine health</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3. VIRTUAL MACHINE ADMINISTRATOR / DEVELOPER
<table>
<thead>
<tr>
<th>Learn</th>
<th>Use</th>
<th>Manage</th>
<th>Additional resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn about OpenShift</td>
<td>Enabling the <code>virtctl</code> client</td>
<td>Viewing logs and events</td>
<td>Getting Support</td>
</tr>
<tr>
<td>Virtualization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creating virtual machines</td>
<td>Monitoring virtual machine health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managing virtual machines</td>
<td>Creating and managing virtual machine snapshots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>instances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controlling virtual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>machine states</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessing the virtual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>machine consoles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass configuration data to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>virtual machines using</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>secrets, configuration maps,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and service accounts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.1. ABOUT RED HAT OPENSHIFT VIRTUALIZATION

Red Hat OpenShift Virtualization enables you to bring traditional virtual machines (VMs) into OpenShift Container Platform where they run alongside containers, and are managed as native Kubernetes objects.

OpenShift Virtualization is represented by the logo.

You can use OpenShift Virtualization with either the OVN-Kubernetes or the OpenShiftSDN default Container Network Interface (CNI) network provider.

Learn more about what you can do with OpenShift Virtualization.

3.1.1. OpenShift Virtualization supported cluster version

OpenShift Virtualization 4.10 is supported for use on OpenShift Container Platform 4.10 clusters. To use the latest z-stream release of OpenShift Virtualization, you must first upgrade to the latest version of OpenShift Container Platform.

3.1.2. Supported guest operating systems

To view the supported guest operating systems for OpenShift Virtualization, refer to Certified Guest Operating Systems in Red Hat OpenStack Platform, Red Hat Virtualization and OpenShift Virtualization.

3.2. 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.

3.3. NEW AND CHANGED FEATURES

- OpenShift Virtualization is certified in Microsoft’s Windows Server Virtualization Validation Program (SVVP) to run Windows Server workloads. The SVVP Certification applies to:
  - Red Hat Enterprise Linux CoreOS workers. In the Microsoft SVVP Catalog, they are named Red Hat OpenShift Container Platform 4 on RHEL CoreOS 8.
  - Intel and AMD CPUs.
- OpenShift Virtualization is now integrated with OpenShift Service Mesh. You can connect virtual machines to a service mesh to monitor, visualize, and control traffic between pods that run virtual machine workloads on the default pod network with IPv4.
- OpenShift Virtualization now provides a unified API for the automatic import and update of predefined boot sources.

3.3.1. Quick starts
Quick start tours are available for several OpenShift Virtualization features. To view the tours, click the Help icon ? in the menu bar on the header of the OpenShift Virtualization console and then select Quick Starts. You can filter the available tours by entering the virtual machine keyword in the Filter field.

3.3.2. Installation

- OpenShift Virtualization workloads, such as virt-launcher pods, now automatically update if they support live migration. You can configure workload update strategies or opt out of future automatic updates by editing the HyperConverged custom resource.

- You can now use OpenShift Virtualization with single node clusters, also known as Single Node OpenShift (SNO).

  NOTE

Single node clusters are not configured for high-availability operation, which results in significant changes to OpenShift Virtualization behavior.

- Resource requests and priority classes are now defined for all OpenShift Virtualization control plane components.

3.3.3. Networking

- You can now configure multiple nmstate-enabled nodes concurrently by using a single NodeNetworkConfigurationPolicy manifest.

- Live migration is now supported by default for virtual machines that are attached to an SR-IOV network interface.

3.3.4. Storage

- Online snapshots are supported for virtual machines that have hot-plugged virtual disks. However, hot-plugged disks that are not in the virtual machine specification are not included in the snapshot.

- You can use the Kubernetes Container Storage Interface (CSI) driver with the hostpath provisioner (HPP) to configure local storage for your virtual machines. Using the CSI driver minimizes disruption to your existing OpenShift Container Platform nodes and clusters when configuring local storage.

3.3.5. Web console

- The OpenShift Virtualization dashboard provides resource consumption data for virtual machines and associated pods. The visualization metrics displayed in the OpenShift Virtualization dashboard are based on Prometheus Query Language (PromQL) queries.

3.4. DEPRECATED AND REMOVED FEATURES

3.4.1. Deprecated features

Deprecated features are included in the current release and supported. However, they will be removed in a future release and are not recommended for new deployments.
In a future release, support for the legacy HPP custom resource, and the associated storage class, will be deprecated. Beginning in OpenShift Virtualization 4.10, the HPP Operator uses the Kubernetes Container Storage Interface (CSI) driver to configure local storage. The Operator continues to support the existing (legacy) format of the HPP custom resource and the associated storage class. If you use the HPP Operator, plan to **create a storage class for the CSI driver** as part of your migration strategy.

### 3.4.2. Removed features

Removed features are not supported in the current release.

- The VM Import Operator has been removed from OpenShift Virtualization with this release. It is replaced by the **Migration Toolkit for Virtualization**.
- This release removes the template for CentOS Linux 8, which reached **End of Life (EOL)** on December 31, 2021. However, OpenShift Container Platform now includes templates for CentOS Stream 8 and CentOS Stream 9.

**NOTE**

All CentOS distributions are community-supported.

### 3.5. TECHNOLOGY PREVIEW FEATURES

Some features in this release are currently in Technology Preview. These experimental features are not intended for production use. The Red Hat Customer Portal provides the **Technology Preview Features Support Scope** for these features:

- You can now use the Red Hat Enterprise Linux 9 Beta template to create virtual machines.
- You can now **deploy OpenShift Virtualization on AWS bare metal nodes**.
- **OpenShift Virtualization critical alerts** now have corresponding descriptions of problems that require immediate attention, reasons for why each alert occurs, a troubleshooting process to diagnose the source of the problem, and steps for resolving each alert.
- A cluster administrator can now back up namespaces that contain VMs by using the **OpenShift API for Data Protection** with the OpenShift Virtualization plug-in.
- Administrators can now declaratively **create and expose mediated devices** such as virtual graphics processing units (vGPUs) by editing the **HyperConverged CR**. Virtual machine owners can then assign these devices to VMs.
- You can **transfer the static IP configuration of the NIC attached to the bridge** by applying a single **NodeNetworkConfigurationPolicy** manifest to the cluster.
- You can now install OpenShift Virtualization on IBM Cloud bare-metal servers. Bare-metal servers offered by other cloud providers are not supported.

### 3.6. BUG FIXES

- If you initiate a cloning operation before the clone source becomes available, the cloning operation now completes successfully without using a workaround. (**BZ#1855182**) 
- Editing a virtual machine fails if the VM references a deleted template that was provided by
OpenShift Virtualization before version 4.8. In OpenShift Virtualization 4.8 and later, deleted OpenShift Virtualization-provided templates are automatically recreated by the OpenShift Virtualization Operator. (BZ#1929165)

- You can now successfully use the **Send Keys** and **Disconnect** buttons when using a virtual machine with a VNC console. (BZ#1964789)

- When you create a virtual machine, its unique fully qualified domain name (FQDN) now contains the cluster domain name. (BZ#1998300)

- If you hot-plug a virtual disk and then force delete the **virt-launcher** pod, you no longer lose data. (BZ#2007397)

- OpenShift Virtualization now issues a HPPSharingPoolPathWithOS alert if you try to install the hostpath provisioner (HPP) on a path that shares the filesystem with other critical components. To use the HPP to provide storage for virtual machine disks, configure it with dedicated storage that is separate from the node’s root filesystem. Otherwise, the node might run out of storage and become non-functional. (BZ#2038985)

- If you provision a virtual machine disk, OpenShift Virtualization now allocates a persistent volume claim (PVC) that is just large enough to accommodate the requested disk size, rather than issuing a KubePersistentVolumeFillingUp alert for each VM disk PVC. You can monitor disk usage from within the virtual machine itself. (BZ#2039489)

- You can now create a virtual machine snapshot for VMs with hot-plugged disks. (BZ#2042908)

- You can now successfully import a VM image when using a cluster-wide proxy configuration. (BZ#2046271)

3.7. KNOWN ISSUES

- If a single node contains more than 50 images, pod scheduling might be imbalanced across nodes. This is because the list of images on a node is shortened to 50 by default. (BZ#1984442)
  - As a workaround, you can disable the image limit by editing the KubeletConfig object and setting the value of nodeStatusMaxImages to -1.

- If you deploy the hostpath provisioner on a cluster where any node has a fully qualified domain name (FQDN) that exceeds 42 characters, the provisioner fails to bind PVCs. (BZ#2057157)

**Example error message**

```
E0222 17:52:54.088950       1 reflector.go:138] k8s.io/client-go/informers/factory.go:134: Failed to watch *v1beta1.CSIStorageCapacity: failed to list *v1beta1.CSIStorageCapacity: unable to parse requirement: values[0][csi.storage.k8s.io/managed-by]: Invalid value: "external-provisioner-<node_FQDN>": must be no more than 63 characters
```

1 Though the error message refers to a maximum of 63 characters, this includes the **external-provisioner**-string that is prefixed to the node’s FQDN.

- As a workaround, disable the **storageCapacity** option in the hostpath provisioner CSI driver by running the following command:
If your OpenShift Container Platform cluster uses OVN-Kubernetes as the default Container Network Interface (CNI) provider, you cannot attach a Linux bridge or bonding device to a host’s default interface because of a change in the host network topology of OVN-Kubernetes. (BZ#1885605)

- As a workaround, you can use a secondary network interface connected to your host, or switch to the OpenShift SDN default CNI provider.

- Running virtual machines that cannot be live migrated might block an OpenShift Container Platform cluster upgrade. This includes virtual machines that use hostpath provisioner storage or SR-IOV network interfaces.

  - As a workaround, you can reconfigure the virtual machines so that they can be powered off during a cluster upgrade. In the spec section of the virtual machine configuration file:

    1. Modify the evictionStrategy and runStrategy fields.

       a. Remove the evictionStrategy: LiveMigrate field. See Configuring virtual machine eviction strategy for more information on how to configure eviction strategy.

       b. Set the runStrategy field to Always.

    2. Set the default CPU model by running the following command:

       ```
       $ oc annotate --overwrite -n openshift-cnv hyperconverged kubevirt-hyperconverged kubevirt.kubevirt.io/jsonpatch='[
       {
         "op": "add",
         "path": "/spec/configuration/cpuModel",
         "value": "<cpu_model>"
       }]
       '
       ```

       Replace <cpu_model> with the actual CPU model value. You can determine this value by running oc describe node <node> for all nodes and looking at the cpu-model=#{name} labels. Select the CPU model that is present on all of your nodes.

- If you use Red Hat Ceph Storage or Red Hat OpenShift Data Foundation Storage, cloning more than 100 VMs at once might fail. (BZ#1989527)

  - As a workaround, you can perform a host-assisted copy by setting spec.cloneStrategy: copy in the storage profile manifest. For example:

```
apiVersion: cdi.kubevirt.io/v1beta1
kind: StorageProfile
metadata:
```
In some instances, multiple virtual machines can mount the same PVC in read-write mode, which might result in data corruption. ([BZ#1992753](#))

- As a workaround, avoid using a single PVC in read-write mode with multiple VMs.

The Pod Disruption Budget (PDB) prevents pod disruptions for migratable virtual machine images. If the PDB detects pod disruption, then `openshift-monitoring` sends a `PodDisruptionBudgetAtLimit` alert every 60 minutes for virtual machine images that use the `LiveMigrate` eviction strategy. ([BZ#2026733](#))

- As a workaround, **Silencing alerts.**

On a large cluster, the OpenShift Virtualization MAC pool manager might take too much time to boot and OpenShift Virtualization might not become ready. ([BZ#2035344](#))

- As a workaround, if you do not require MAC pooling functionality, then disable this sub-component by running the following command:

```bash
$ oc annotate --overwrite -n openshift-cnv hco kubevirt-hyperconverged 'networkaddonsconfigs.kubevirt.io/jsonpatch=[
    {
        "op": "replace"
        "path": "/spec/kubeMacPool"
        "value": null
    }
]
```

OpenShift Virtualization links a service account token in use by a pod to that specific pod. OpenShift Virtualization implements a service account volume by creating a disk image that contains a token. If you migrate a VM, then the service account volume becomes invalid. ([BZ#2037611](#))

- As a workaround, use user accounts rather than service accounts because user account tokens are not bound to a specific pod.

If a VM crashes or hangs during shutdown, new shutdown requests do not stop the VM. ([BZ#2040766](#))

If you configure the `HyperConverged` custom resource (CR) to enable mediated devices before drivers are installed, enablement of mediated devices does not occur. This issue can be triggered by updates. For example, if `virt-handler` is updated before `daemonset`, which installs NVIDIA drivers, then nodes cannot provide virtual machine GPUs. ([BZ#2046298](#))
As a workaround:

1. Remove `mediatedDevicesConfiguration` and `permittedHostDevices` from the `HyperConverged` CR.

2. Update both `mediatedDevicesConfiguration` and `permittedHostDevices` stanzas with the configuration you want to use.

- YAML examples in the VM wizard are hardcoded and do not always contain the latest upstream changes. (BZ#2055492)

- If you clone more than 100 VMs using the `csi-clone` cloning strategy, then the Ceph CSI might not purge the clones. Manually deleting the clones can also fail. (BZ#2055595)
  - As a workaround, you can restart the `ceph-mgr` to purge the VM clones.

- A non-privileged user cannot use the Add Network Interface button on the VM Network Interfaces tab. (BZ#2056420)
  - As a workaround, non-privileged users can add additional network interfaces while creating the VM by using the VM wizard.

- A non-privileged user cannot add disks to a VM due to RBAC rules. (BZ#2056421)
  - As a workaround, manually add the RBAC rule to allow specific users to add disks.

- The web console does not display virtual machine templates that are deployed to a custom namespace. Only templates deployed to the default namespace display in the web console. (BZ#2054650)
  - As a workaround, avoid deploying templates to a custom namespace.
CHAPTER 4. INSTALLING

4.1. CONFIGURING YOUR CLUSTER FOR OPENSHIFT VIRTUALIZATION

Before you install OpenShift Virtualization, ensure that your OpenShift Container Platform cluster meets the following requirements:

- Your cluster must be installed on on-premise bare metal infrastructure with Red Hat Enterprise Linux CoreOS (RHCOS) workers. You can use any installation method including user-provisioned, installer-provisioned, or assisted installer to deploy your cluster.

  **NOTE**

  OpenShift Virtualization only supports RHCOS worker nodes. RHEL 7 or RHEL 8 nodes are not supported.

- You can install OpenShift Virtualization on Amazon Web Services (AWS) bare metal instances. Bare metal instances offered by other cloud providers are not supported.

  **IMPORTANT**

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

  For more information about the support scope of Red Hat Technology Preview features, see [https://access.redhat.com/support/offerings/techpreview/](https://access.redhat.com/support/offerings/techpreview/).

- Additionally, there are three options to maintain high availability (HA) of virtual machines:
  
  o Use installer-provisioned infrastructure and deploy machine health checks.

    **NOTE**

    In OpenShift Virtualization clusters installed using installer-provisioned infrastructure and with MachineHealthCheck properly configured, if a node fails the MachineHealthCheck and becomes unavailable to the cluster, it is recycled. What happens next with VMs that ran on the failed node depends on a series of conditions. See About RunStrategies for virtual machines for more detailed information about the potential outcomes and how RunStrategies affect those outcomes.

    o If you are not using installer-provisioned infrastructure, use either a monitoring system or a qualified human to monitor node availability. When a node is lost, shut it down and run `oc delete node <lost_node>`.

    **NOTE**

    Without an external monitoring system or a qualified human monitoring node health, virtual machines lose high availability.
Use the Node Health Check Operator on any OpenShift Container Platform cluster to deploy the NodeHealthCheck controller. The controller identifies unhealthy nodes and uses the Poison Pill Operator to remediate the unhealthy nodes.

IMPORTANT

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

For more information about the support scope of Red Hat Technology Preview features, see https://access.redhat.com/support/offerings/techpreview/.

- Shared storage is required to enable live migration.
- You must manage your Compute nodes according to the number and size of the virtual machines that you want to host in the cluster.
- If you have limited internet connectivity, you can configure proxy support in Operator Lifecycle Manager to access the Red Hat-provided OperatorHub. If you are using a restricted network with no internet connectivity, you must configure Operator Lifecycle Manager for restricted networks.
- If your cluster uses worker nodes with different CPUs, live migration failures can occur because different CPUs have different capacities. To avoid such failures, use CPUs with appropriate capacity for each node and set node affinity on your virtual machines to ensure successful migration. See Configuring a required node affinity rule for more information.
- All CPUs must be supported by Red Hat Enterprise Linux 8 and meet the following requirements:
  - Intel 64 or AMD64 CPU extensions are supported
  - Intel VT or AMD-V hardware virtualization extensions are enabled
  - The no-execute (NX) flag is enabled
- If FIPS mode is enabled for your cluster, no additional setup is needed for OpenShift Virtualization. Support for FIPS cryptography must be enabled before the operating system that your cluster uses boots for the first time.

OpenShift Virtualization works with OpenShift Container Platform by default, but the following installation configurations are recommended:

- Configure monitoring in the cluster.

NOTE

To obtain an evaluation version of OpenShift Container Platform, download a trial from the OpenShift Container Platform home page.
4.1.1. Changes in OpenShift Virtualization behavior on a single node cluster

You can use OpenShift Virtualization with single node clusters, also known as Single Node OpenShift (SNO). These clusters are not configured for high-availability operation, which results in significant changes to OpenShift Virtualization behavior.

- OpenShift Virtualization components have only one replica, and pod disruption budgets do not apply.
- Live migration is not supported.
- Due to differences in storage behavior, some virtual machine templates are incompatible with SNO. To ensure compatibility, do not set the `evictionStrategy` field for any templates or virtual machines that use data volumes or storage profiles.

Additional resources

- High-availability or single node cluster detection and support

4.1.2. Additional hardware requirements for OpenShift Virtualization

OpenShift Virtualization is an add-on to OpenShift Container Platform and imposes additional overhead that you must account for when planning a cluster. Each cluster machine must accommodate the following overhead requirements in addition to the OpenShift Container Platform requirements. Oversubscribing the physical resources in a cluster can affect performance.

**IMPORTANT**

The numbers noted in this documentation are based on Red Hat’s test methodology and setup. These numbers can vary based on your own individual setup and environments.

4.1.2.1. Memory overhead

Calculate the memory overhead values for OpenShift Virtualization by using the equations below.

**Cluster memory overhead**

- Memory overhead per infrastructure node ≈ 150 MiB
- Memory overhead per worker node ≈ 360 MiB

Additionally, OpenShift Virtualization environment resources require a total of 2179 MiB of RAM that is spread across all infrastructure nodes.

**Virtual machine memory overhead**

\[
\text{Memory overhead per virtual machine} = (1.002 \times \text{requested memory}) + 146 \text{ MiB} \ \\ \ + 8 \text{ MiB} \times (\text{number of vCPUs}) \ \\ \ + 16 \text{ MiB} \times (\text{number of graphics devices})
\]

1. Number of virtual CPUs requested by the virtual machine
2. Number of virtual graphics cards requested by the virtual machine
If your environment includes a Single Root I/O Virtualization (SR-IOV) network device or a Graphics Processing Unit (GPU), allocate 1 GiB additional memory overhead for each device.

4.1.2.2. CPU overhead

Calculate the cluster processor overhead requirements for OpenShift Virtualization by using the equation below. The CPU overhead per virtual machine depends on your individual setup.

Cluster CPU overhead

- CPU overhead for infrastructure nodes ≈ 4 cores

OpenShift Virtualization increases the overall utilization of cluster level services such as logging, routing, and monitoring. To account for this workload, ensure that nodes that host infrastructure components have capacity allocated for 4 additional cores (4000 millicores) distributed across those nodes.

- CPU overhead for worker nodes ≈ 2 cores + CPU overhead per virtual machine

Each worker node that hosts virtual machines must have capacity for 2 additional cores (2000 millicores) for OpenShift Virtualization management workloads in addition to the CPUs required for virtual machine workloads.

Virtual machine CPU overhead

If dedicated CPUs are requested, there is a 1:1 impact on the cluster CPU overhead requirement. Otherwise, there are no specific rules about how many CPUs a virtual machine requires.

4.1.2.3. Storage overhead

Use the guidelines below to estimate storage overhead requirements for your OpenShift Virtualization environment.

Cluster storage overhead

- Aggregated storage overhead per node ≈ 10 GiB

10 GiB is the estimated on-disk storage impact for each node in the cluster when you install OpenShift Virtualization.

Virtual machine storage overhead

Storage overhead per virtual machine depends on specific requests for resource allocation within the virtual machine. The request could be for ephemeral storage on the node or storage resources hosted elsewhere in the cluster. OpenShift Virtualization does not currently allocate any additional ephemeral storage for the running container itself.

4.1.2.4. Example

As a cluster administrator, if you plan to host 10 virtual machines in the cluster, each with 1 GiB of RAM and 2 vCPUs, the memory impact across the cluster is 11.68 GiB. The estimated on-disk storage impact for each node in the cluster is 10 GiB and the CPU impact for worker nodes that host virtual machine workloads is a minimum of 2 cores.
4.2. PLANNING YOUR ENVIRONMENT ACCORDING TO OPENSФFT VIRTUALIZATION OBJECT MAXIMUMS

Plan your cluster for OpenShift Virtualization by using tested object maximums as guidelines.

4.2.1. About cluster limits for OpenShift Virtualization

To view the supported cluster limits for guests, hosts, and other objects, refer to Supported Limits for OpenShift Virtualization 4.x.

Red Hat has tested these values to ensure optimal cluster and workload performance. Exceeding the documented limits might result in unexpected behavior and degraded performance.

**NOTE**

Guidelines for object maximums are based on the largest possible cluster. For smaller clusters, the maximums are lower.

4.2.2. Additional resources

- Planning your environment according to object maximums

4.3. SPECIFYING NODES FOR OPENSФFT VIRTUALIZATION COMPONENTS

Specify the nodes where you want to deploy OpenShift Virtualization Operators, workloads, and controllers by configuring node placement rules.

**NOTE**

You can configure node placement for some components after installing OpenShift Virtualization, but there must not be virtual machines present if you want to configure node placement for workloads.

4.3.1. About node placement for virtualization components

You might want to customize where OpenShift Virtualization deploys its components to ensure that:

- Virtual machines only deploy on nodes that are intended for virtualization workloads.
- Operators only deploy on infrastructure nodes.
- Certain nodes are unaffected by OpenShift Virtualization. For example, you have workloads unrelated to virtualization running on your cluster, and you want those workloads to be isolated from OpenShift Virtualization.

4.3.1.1. How to apply node placement rules to virtualization components

You can specify node placement rules for a component by editing the corresponding object directly or by using the web console.
For the OpenShift Virtualization Operators that Operator Lifecycle Manager (OLM) deploys, edit the OLM Subscription object directly. Currently, you cannot configure node placement rules for the Subscription object by using the web console.

For components that the OpenShift Virtualization Operators deploy, edit the HyperConverged object directly or configure it by using the web console during OpenShift Virtualization installation.

For the hostpath provisioner, edit the HostPathProvisioner object directly or configure it by using the web console.

**WARNING**

You must schedule the hostpath provisioner and the virtualization components on the same nodes. Otherwise, virtualization pods that use the hostpath provisioner cannot run.

Depending on the object, you can use one or more of the following rule types:

- **nodeSelector**
  - Allows pods to be scheduled on nodes that are labeled with the key-value pair or pairs that you specify in this field. The node must have labels that exactly match all listed pairs.

- **affinity**
  - Enables you to use more expressive syntax to set rules that match nodes with pods. Affinity also allows for more nuance in how the rules are applied. For example, you can specify that a rule is a preference, rather than a hard requirement, so that pods are still scheduled if the rule is not satisfied.

- **tolerations**
  - Allows pods to be scheduled on nodes that have matching taints. If a taint is applied to a node, that node only accepts pods that tolerate the taint.

### 4.3.1.2. Node placement in the OLM Subscription object

To specify the nodes where OLM deploys the OpenShift Virtualization Operators, edit the Subscription object during OpenShift Virtualization installation. You can include node placement rules in the `spec.config` field, as shown in the following example:

```yaml
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: hco-operatorhub
  namespace: openshift-cnv
spec:
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  name: kubevirt-hyperconverged
  startingCSV: kubevirt-hyperconverged-operator.v4.10.0
  channel: "stable"
  config: 1
```

The config field supports nodeSelector and tolerations, but it does not support affinity.

### 4.3.1.3. Node placement in the HyperConverged object

To specify the nodes where OpenShift Virtualization deploys its components, you can include the nodePlacement object in the HyperConverged Cluster custom resource (CR) file that you create during OpenShift Virtualization installation. You can include nodePlacement under the spec.infra and spec.workloads fields, as shown in the following example:

```yaml
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kbevrit-hyperconverged
  namespace: openshift-cnv
spec:
  infra:
    nodePlacement: 1
  workloads:
    nodePlacement:
```

The nodePlacement fields support nodeSelector, affinity, and tolerations fields.

### 4.3.1.4. Node placement in the HostPathProvisioner object

You can configure node placement rules in the spec.workload field of the HostPathProvisioner object that you create when you install the hostpath provisioner.

```yaml
apiVersion: hostpathprovisioner.kubevirt.io/v1beta1
kind: HostPathProvisioner
metadata:
  name: hostpath-provisioner
spec:
  imagePullPolicy: IfNotPresent
  pathConfig:
    path: "</path/to/backing/directory>"
    useNamingPrefix: false
  workload: 1
```

The workload field supports nodeSelector, affinity, and tolerations fields.

### 4.3.1.5. Additional resources

- Specifying nodes for virtual machines
- Placing pods on specific nodes using node selectors
- Controlling pod placement on nodes using node affinity rules
- Controlling pod placement using node taints
4.3.2. Example manifests

The following example YAML files use nodePlacement, affinity, and tolerations objects to customize node placement for OpenShift Virtualization components.

4.3.2.1. Operator Lifecycle Manager Subscription object

4.3.2.1.1. Example: Node placement with nodeSelector in the OLM Subscription object

In this example, nodeSelector is configured so that OLM places the OpenShift Virtualization Operators on nodes that are labeled with example.io/example-infra-key = example-infra-value.

```yaml
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: hco-operatorhub
  namespace: openshift-cnv
spec:
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  name: kubevirt-hyperconverged
  startingCSV: kubevirt-hyperconverged-operator.v4.10.0
  channel: "stable"
  config:
    nodeSelector:
      example.io/example-infra-key: example-infra-value
```

4.3.2.1.2. Example: Node placement with tolerations in the OLM Subscription object

In this example, nodes that are reserved for OLM to deploy OpenShift Virtualization Operators are labeled with the key=virtualization:NoSchedule taint. Only pods with the matching tolerations are scheduled to these nodes.

```yaml
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: hco-operatorhub
  namespace: openshift-cnv
spec:
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  name: kubevirt-hyperconverged
  startingCSV: kubevirt-hyperconverged-operator.v4.10.0
  channel: "stable"
  config:
    tolerations:
      - key: "key"
```

- Installing OpenShift Virtualization using the CLI
- Installing OpenShift Virtualization using the web console
- Configuring local storage for virtual machines
4.3.2.2. HyperConverged object

4.3.2.2.1. Example: Node placement with nodeSelector in the HyperConverged Cluster CR

In this example, **nodeSelector** is configured so that infrastructure resources are placed on nodes that are labeled with `example.io/example-infra-key = example-infra-value` and workloads are placed on nodes labeled with `example.io/example-workloads-key = example-workloads-value`.

```
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  infra:
    nodePlacement:
      nodeSelector:
        example.io/example-infra-key: example-infra-value
  workloads:
    nodePlacement:
      nodeSelector:
        example.io/example-workloads-key: example-workloads-value
```

4.3.2.2.2. Example: Node placement with affinity in the HyperConverged Cluster CR

In this example, **affinity** is configured so that infrastructure resources are placed on nodes that are labeled with `example.io/example-infra-key = example-value` and workloads are placed on nodes labeled with `example.io/example-workloads-key = example-workloads-value`. Nodes that have more than eight CPUs are preferred for workloads, but if they are not available, pods are still scheduled.

```
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  infra:
    nodePlacement:
      affinity:
        nodeAffinity:
          requiredDuringSchedulingIgnoredDuringExecution:
            nodeSelectorTerms:
              - matchExpressions:
                  - key: example.io/example-infra-key
                    operator: In
                    values:
                      - example-infra-value
```

34
4.3.2.2.3. Example: Node placement with tolerations in the HyperConverged Cluster CR

In this example, nodes that are reserved for OpenShift Virtualization components are labeled with the key=virtualization:NoSchedule taint. Only pods with the matching tolerations are scheduled to these nodes.

```yaml
nodeAffinity:
  requiredDuringSchedulingIgnoredDuringExecution:
    nodeSelectorTerms:
      - matchExpressions:
          - key: example.io/example-workloads-key
            operator: In
            values: [example-workloads-value]

preferredDuringSchedulingIgnoredDuringExecution:
  - weight: 1
    preference:
      matchExpressions:
        - key: example.io/num-cpus
          operator: Gt
          values: [8]
```

4.3.2.3. HostPathProvisioner object

4.3.2.3.1. Example: Node placement with nodeSelector in the HostPathProvisioner object

In this example, nodeSelector is configured so that workloads are placed on nodes labeled with example.io/example-workloads-key = example-workloads-value.

```yaml
apiVersion: hostpathprovisioner.kubevirt.io/v1beta1
kind: HostPathProvisioner
metadata:
  name: hostpath-provisioner
spec:
  imagePullPolicy: IfNotPresent
  pathConfig:
    path: "</path/to/backing/directory>"
  useNamingPrefix: false
```
4.4. INSTALLING OPENSSHIFT VIRTUALIZATION USING THE WEB CONSOLE

Install OpenShift Virtualization to add virtualization functionality to your OpenShift Container Platform cluster.

You can use the OpenShift Container Platform 4.10 web console to subscribe to and deploy the OpenShift Virtualization Operators.

4.4.1. Installing the OpenShift Virtualization Operator

You can install the OpenShift Virtualization Operator from the OpenShift Container Platform web console.

Prerequisites

- Install OpenShift Container Platform 4.10 on your cluster.
- Log in to the OpenShift Container Platform web console as a user with `cluster-admin` permissions.

Procedure

1. From the Administrator perspective, click Operators → OperatorHub.
2. In the Filter by keyword field, type OpenShift Virtualization.
3. Select the OpenShift Virtualization tile.
4. Read the information about the Operator and click Install.
5. On the Install Operator page:
   a. Select stable from the list of available Update Channel options. This ensures that you install the version of OpenShift Virtualization that is compatible with your OpenShift Container Platform version.
   b. For Installed Namespace, ensure that the Operator recommended namespace option is selected. This installs the Operator in the mandatory `openshift-cnv` namespace, which is automatically created if it does not exist.

WARNING

Attempting to install the OpenShift Virtualization Operator in a namespace other than `openshift-cnv` causes the installation to fail.
c. For **Approval Strategy**, it is highly recommended that you select **Automatic**, which is the default value, so that OpenShift Virtualization automatically updates when a new version is available in the **stable** update channel. While it is possible to select the **Manual** approval strategy, this is inadvisable because of the high risk that it presents to the supportability and functionality of your cluster. Only select **Manual** if you fully understand these risks and cannot use **Automatic**.

### WARNING

Because OpenShift Virtualization is only supported when used with the corresponding OpenShift Container Platform version, missing OpenShift Virtualization updates can cause your cluster to become unsupported.

6. Click **Install** to make the Operator available to the `openshift-cnv` namespace.

7. When the Operator installs successfully, click **Create HyperConverged**.

8. Optional: Configure **Infra** and **Workloads** node placement options for OpenShift Virtualization components.

9. Click **Create** to launch OpenShift Virtualization.

**Verification**

- Navigate to the **Workloads → Pods** page and monitor the OpenShift Virtualization pods until they are all **Running**. After all the pods display the **Running** state, you can use OpenShift Virtualization.

**4.4.2. Next steps**

You might want to additionally configure the following components:

- The **hostpath provisioner** is a local storage provisioner designed for OpenShift Virtualization. If you want to configure local storage for virtual machines, you must enable the hostpath provisioner first.

**4.5. INSTALLING OPENSHIFT VIRTUALIZATION USING THE CLI**

Install OpenShift Virtualization to add virtualization functionality to your OpenShift Container Platform cluster. You can subscribe to and deploy the OpenShift Virtualization Operators by using the command line to apply manifests to your cluster.

### NOTE

To specify the nodes where you want OpenShift Virtualization to install its components, configure node placement rules.

**4.5.1. Prerequisites**
- Install OpenShift Container Platform 4.10 on your cluster.
- Install the OpenShift CLI (``oc``).
- Log in as a user with `cluster-admin` privileges.

### 4.5.2. Subscribing to the OpenShift Virtualization catalog by using the CLI

Before you install OpenShift Virtualization, you must subscribe to the OpenShift Virtualization catalog. Subscribing gives the `openshift-cnv` namespace access to the OpenShift Virtualization Operators.

To subscribe, configure `Namespace`, `OperatorGroup`, and `Subscription` objects by applying a single manifest to your cluster.

**Procedure**

1. Create a YAML file that contains the following manifest:

```yaml
apiVersion: v1
kind: Namespace
metadata:
  name: openshift-cnv
---
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: kubevirt-hyperconverged-group
  namespace: openshift-cnv
spec:
  targetNamespaces:
    - openshift-cnv
---
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: hco-operatorhub
  namespace: openshift-cnv
spec:
  source: redhat-operators
  sourceNamespace: openshift-marketplace
  name: kubevirt-hyperconverged
  startingCSV: kubevirt-hyperconverged-operator.v4.10.0
  channel: "stable"
```

1. Using the `stable` channel ensures that you install the version of OpenShift Virtualization that is compatible with your OpenShift Container Platform version.

2. Create the required `Namespace`, `OperatorGroup`, and `Subscription` objects for OpenShift Virtualization by running the following command:

```
$ oc apply -f <file name>.yaml
```
NOTE
You can configure certificate rotation parameters in the YAML file.

4.5.3. Deploying the OpenShift Virtualization Operator by using the CLI

You can deploy the OpenShift Virtualization Operator by using the `oc` CLI.

**Prerequisites**

- An active subscription to the OpenShift Virtualization catalog in the `openshift-cnv` namespace.

**Procedure**

1. Create a YAML file that contains the following manifest:

   ```yaml
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
     namespace: openshift-cnv
   spec:
   
   $ oc apply -f <file_name>.yaml
   
2. Deploy the OpenShift Virtualization Operator by running the following command:

   ```bash
   $ oc apply -f <file_name>.yaml
   
**Verification**

- Ensure that OpenShift Virtualization deployed successfully by watching the PHASE of the cluster service version (CSV) in the `openshift-cnv` namespace. Run the following command:

   ```bash
   $ watch oc get csv -n openshift-cnv
   
   The following output displays if deployment was successful:

   **Example output**

   NAME                                      DISPLAY                    VERSION   REPLACES   PHASE
   kubevirt-hyperconverged-operator.v4.10.0   OpenShift Virtualization   4.10.0     4.10.0     Succeeded

4.5.4. Next steps

You might want to additionally configure the following components:

- The hostpath provisioner is a local storage provisioner designed for OpenShift Virtualization. If you want to configure local storage for virtual machines, you must enable the hostpath provisioner first.

**4.6. ENABLING THE VIRTCCTL CLIENT**
The **virtctl** client is a command-line utility for managing OpenShift Virtualization resources. It is available for Linux, macOS, and Windows distributions.

### 4.6.1. Downloading and installing the virtctl client

#### 4.6.1.1. Downloading the virtctl client

Download the **virtctl** client by using the link provided in the `ConsoleCLIDownload` custom resource (CR).

**Procedure**

1. View the `ConsoleCLIDownload` object by running the following command:
   
   ```
   $ oc get ConsoleCLIDownload virtctl-clidownloads-kubevirt-hyperconverged -o yaml
   ```

2. Download the **virtctl** client by using the link listed for your distribution.

#### 4.6.1.2. Installing the virtctl client

Extract and install the **virtctl** client after downloading from the appropriate location for your operating system.

**Prerequisites**

- You must have downloaded the **virtctl** client.

**Procedure**

- For Linux:
  
  1. Extract the tarball. The following CLI command extracts it into the same directory as the tarball:
     
     ```
     $ tar -xvf <virtctl-version-distribution.arch>.tar.gz
     ```
  
  2. Navigate the extracted folder hierarchy and run the following command to make the **virtctl** binary executable:
     
     ```
     $ chmod +x <virtctl-file-name>
     ```
  
  3. Move the **virtctl** binary to a directory in your **PATH** environment variable.
  
  4. To check your path, run the following command:
     
     ```
     $ echo $PATH
     ```

- For Windows users:
  
  1. Unpack and unzip the archive.
  
  2. Navigate the extracted folder hierarchy and double-click the **virtctl** executable file to install the client.
3. Move the `virtctl` binary to a directory in your PATH environment variable.

4. To check your path, run the following command:
   
   ```
   C:\> path
   ```

   - For macOS users:
     1. Unpack and unzip the archive.
     2. Move the `virtctl` binary to a directory in your PATH environment variable.
     3. To check your path, run the following command:
        
        ```
        echo $PATH
        ```

4.6.2. Additional setup options

4.6.2.1. Installing the `virtctl` client using the yum utility

Install the `virtctl` client from the `kubevirt-virtctl` package.

**Procedure**

- Install the `kubevirt-virtctl` package:
  
  ```
  # yum install kubevirt-virtctl
  ```

4.6.2.2. Enabling OpenShift Virtualization repositories

Red Hat offers OpenShift Virtualization repositories for both Red Hat Enterprise Linux 8 and Red Hat Enterprise Linux 7:

- Red Hat Enterprise Linux 8 repository: `cnv-4.10-for-rhel-8-x86_64-rpms`
- Red Hat Enterprise Linux 7 repository: `rhel-7-server-cnv-4.10-rpms`

The process for enabling the repository in `subscription-manager` is the same in both platforms.

**Procedure**

- Enable the appropriate OpenShift Virtualization repository for your system by running the following command:
  
  ```
  # subscription-manager repos --enable <repository>
  ```

4.6.3. Additional resources

- Using the CLI tools for OpenShift Virtualization.

4.7. UNINSTALLING OPENSHIFT VIRTUALIZATION USING THE WEB CONSOLE
You can uninstall OpenShift Virtualization by using the OpenShift Container Platform web console.

4.7.1. Prerequisites

- You must have OpenShift Virtualization 4.10 installed.
- You must delete all virtual machines, virtual machine instances, and data volumes.

**IMPORTANT**

Attempting to uninstall OpenShift Virtualization without deleting these objects results in failure.

4.7.2. Deleting the OpenShift Virtualization Operator Deployment custom resource

To uninstall OpenShift Virtualization, you must first delete the OpenShift Virtualization Operator Deployment custom resource.

**Prerequisites**

- Create the OpenShift Virtualization Operator Deployment custom resource.

**Procedure**

1. From the OpenShift Container Platform web console, select openshift-cnv from the Projects list.
2. Navigate to the Operators → Installed Operators page.
3. Click OpenShift Virtualization.
4. Click the OpenShift Virtualization Operator Deployment tab.
5. Click the Options menu in the row containing the kubevirt-hyperconverged custom resource. In the expanded menu, click Delete HyperConverged Cluster.
6. Click Delete in the confirmation window.
7. Navigate to the Workloads → Pods page to verify that only the Operator pods are running.
8. Open a terminal window and clean up the remaining resources by running the following command:
   
   ```
   $ oc delete apiservices v1alpha3.subresources.kubevirt.io -n openshift-cnv
   ```

4.7.3. Deleting the OpenShift Virtualization catalog subscription

To finish uninstalling OpenShift Virtualization, delete the OpenShift Virtualization catalog subscription.

**Prerequisites**

- An active subscription to the OpenShift Virtualization catalog
Procedure

1. Navigate to the Operators → OperatorHub page.
2. Search for OpenShift Virtualization and then select it.
3. Click Uninstall.

NOTE
You can now delete the openshift-cnv namespace.

4.7.4. Deleting a namespace using the web console

You can delete a namespace by using the OpenShift Container Platform web console.

NOTE
If you do not have permissions to delete the namespace, the Delete Namespace option is not available.

Procedure

1. Navigate to Administration → Namespaces.
2. Locate the namespace that you want to delete in the list of namespaces.
3. On the far right side of the namespace listing, select Delete Namespace from the Options menu.
4. When the Delete Namespace pane opens, enter the name of the namespace that you want to delete in the field.
5. Click Delete.

4.8. UNINSTALLING OPENSIFT VIRTUALIZATION USING THE CLI

You can uninstall OpenShift Virtualization by using the OpenShift Container Platform CLI.

4.8.1. Prerequisites

- You must have OpenShift Virtualization 4.10 installed.
- You must delete all virtual machines, virtual machine instances, and data volumes.

IMPORTANT
Attempting to uninstall OpenShift Virtualization without deleting these objects results in failure.

4.8.2. Deleting OpenShift Virtualization
You can delete OpenShift Virtualization by using the CLI.

**Prerequisites**

- Install the OpenShift CLI (`oc`).
- Access to a OpenShift Virtualization cluster using an account with `cluster-admin` permissions.

**NOTE**

When you delete the subscription of the OpenShift Virtualization operator in the OLM by using the CLI, the `ClusterServiceVersion` (CSV) object is not deleted from the cluster. To completely uninstall OpenShift Virtualization, you must explicitly delete the CSV.

**Procedure**

1. Delete the **HyperConverged** custom resource:

   ```bash
   $ oc delete HyperConverged kubevirt-hyperconverged -n openshift-cnv
   ```

2. Delete the subscription of the OpenShift Virtualization operator in the Operator Lifecycle Manager (OLM):

   ```bash
   $ oc delete subscription kubevirt-hyperconverged -n openshift-cnv
   ```

3. Set the cluster service version (CSV) name for OpenShift Virtualization as an environment variable:

   ```bash
   $ CSV_NAME=$(oc get csv -n openshift-cnv -o=custom-columns=:metadata.name)
   ```

4. Delete the CSV from the OpenShift Virtualization cluster by specifying the CSV name from the previous step:

   ```bash
   $ oc delete csv ${CSV_NAME} -n openshift-cnv
   ```

OpenShift Virtualization is uninstalled when a confirmation message indicates that the CSV was deleted successfully:

**Example output**

```
clusterserviceversion.operators.coreos.com "kubevirt-hyperconverged-operator.v4.10.0" deleted
```
CHAPTER 5. UPDATING OPENSHIFT VIRTUALIZATION

Learn how Operator Lifecycle Manager (OLM) delivers z-stream and minor version updates for OpenShift Virtualization.

5.1. ABOUT UPDATING OPENSHIFT VIRTUALIZATION

- Operator Lifecycle Manager (OLM) manages the lifecycle of the OpenShift Virtualization Operator. The Marketplace Operator, which is deployed during OpenShift Container Platform installation, makes external Operators available to your cluster.


- OpenShift Virtualization subscriptions use a single update channel that is named stable. The stable channel ensures that your OpenShift Virtualization and OpenShift Container Platform versions are compatible.

- If your subscription’s approval strategy is set to Automatic, the update process starts as soon as a new version of the Operator is available in the stable channel. It is highly recommended to use the Automatic approval strategy to maintain a supportable environment. Each minor version of OpenShift Virtualization is only supported if you run the corresponding OpenShift Container Platform version. For example, you must run OpenShift Virtualization 4.10 on OpenShift Container Platform 4.10.

  - Though it is possible to select the Manual approval strategy, this is not recommended because it risks the supportability and functionality of your cluster. With the Manual approval strategy, you must manually approve every pending update. If OpenShift Container Platform and OpenShift Virtualization updates are out of sync, your cluster becomes unsupported.

- The amount of time an update takes to complete depends on your network connection. Most automatic updates complete within fifteen minutes.

- Updating OpenShift Virtualization does not interrupt network connections.

- Data volumes and their associated persistent volume claims are preserved during update.

IMPORTANT

If you have virtual machines running that use hostpath provisioner storage, they cannot be live migrated and might block an OpenShift Container Platform cluster update.

As a workaround, you can reconfigure the virtual machines so that they can be powered off automatically during a cluster update. Remove the evictionStrategy: LiveMigrate field and set the runStrategy field to Always.

5.2. CONFIGURING AUTOMATIC WORKLOAD UPDATES

5.2.1. About workload updates
When you update OpenShift Virtualization, virtual machine workloads, including `libvirt`, `virt-launcher`, and `qemu`, update automatically if they support live migration.

**NOTE**

Each virtual machine has a `virt-launcher` pod that runs the virtual machine instance (VMI). The `virt-launcher` pod runs an instance of `libvirt`, which is used to manage the virtual machine (VM) process.

You can configure how workloads are updated by editing the `spec.workloadUpdateStrategy` stanza of the `HyperConverged` custom resource (CR). There are two available workload update methods: `LiveMigrate` and `Evict`.

Because the `Evict` method shuts down VMI pods, only the `LiveMigrate` update strategy is enabled by default.

When `LiveMigrate` is the only update strategy enabled:

- VMIs that support live migration are migrated during the update process. The VM guest moves into a new pod with the updated components enabled.
- VMIs that do not support live migration are not disrupted or updated.
  - If a VMI has the `LiveMigrate` eviction strategy but does not support live migration, it is not updated.

If you enable both `LiveMigrate` and `Evict`:

- VMIs that support live migration use the `LiveMigrate` update strategy.
- VMIs that do not support live migration use the `Evict` update strategy. If a VMI is controlled by a `VirtualMachine` object that has a `runStrategy` value of `always`, a new VMI is created in a new pod with updated components.

**Migration attempts and timeouts**

When updating workloads, live migration fails if a pod is in the `Pending` state for the following periods:

- **5 minutes**
  - If the pod is pending because it is `Unschedulable`.
- **15 minutes**
  - If the pod is stuck in the pending state for any reason.

When a VMI fails to migrate, the `virt-controller` tries to migrate it again. It repeats this process until all migratable VMIs are running on new `virt-launcher` pods. If a VMI is improperly configured, however, these attempts can repeat indefinitely.

**NOTE**

Each attempt corresponds to a migration object. Only the five most recent attempts are held in a buffer. This prevents migration objects from accumulating on the system while retaining information for debugging.

**5.2.2. Configuring workload update methods**

You can configure workload update methods by editing the `HyperConverged` custom resource (CR).
Prerequisites

- To use live migration as an update method, you must first enable live migration in the cluster.

**NOTE**

If a `VirtualMachineInstance` CR contains `evictionStrategy: LiveMigrate` and the virtual machine instance (VMI) does not support live migration, the VMI will not update.

Procedure

1. To open the `HyperConverged` CR in your default editor, run the following command:

   ```bash
   $ oc edit hco -n openshift-cnv kubevirt-hyperconverged
   ```

2. Edit the `workloadUpdateStrategy` stanza of the `HyperConverged` CR. For example:

   ```yaml
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
   spec:
     workloadUpdateStrategy:
       workloadUpdateMethods:
       - LiveMigrate
       - Evict
     batchEvictionSize: 10
     batchEvictionInterval: "1m0s"
   ...
   ```

   **1** The methods that can be used to perform automated workload updates. The available values are `LiveMigrate` and `Evict`. If you enable both options as shown in this example, updates use `LiveMigrate` for VMIs that support live migration and `Evict` for any VMIs that do not support live migration. To disable automatic workload updates, you can either remove the `workloadUpdateStrategy` stanza or set `workloadUpdateMethods: []` to leave the array empty.

   **2** The least disruptive update method. VMIs that support live migration are updated by migrating the virtual machine (VM) guest into a new pod with the updated components enabled. If `LiveMigrate` is the only workload update method listed, VMIs that do not support live migration are not disrupted or updated.

   **3** A disruptive method that shuts down VMI pods during upgrade. `Evict` is the only update method available if live migration is not enabled in the cluster. If a VMI is controlled by a `VirtualMachine` object that has `runStrategy: always` configured, a new VMI is created in a new pod with updated components.

   **4** The number of VMIs that can be forced to be updated at a time by using the `Evict` method. This does not apply to the `LiveMigrate` method.

   **5** The interval to wait before evicting the next batch of workloads. This does not apply to the `LiveMigrate` method.
NOTE

You can configure live migration limits and timeouts by editing the `spec.liveMigrationConfig` stanza of the `HyperConverged` CR.

3. To apply your changes, save and exit the editor.

5.3. APPROVING PENDING OPERATOR UPDATES

5.3.1. Manually approving a pending Operator upgrade

If an installed Operator has the approval strategy in its subscription set to Manual, when new updates are released in its current update channel, the update must be manually approved before installation can begin.

Prerequisites

- An Operator previously installed using Operator Lifecycle Manager (OLM).

Procedure

1. In the Administrator perspective of the OpenShift Container Platform web console, navigate to `Operators → Installed Operators`.
2. Operators that have a pending upgrade display a status with **Upgrade available**. Click the name of the Operator you want to upgrade.
3. Click the **Subscription** tab. Any upgrades requiring approval are displayed next to **Upgrade Status**. For example, it might display **1 requires approval**.
4. Click **1 requires approval**, then click **Preview Install Plan**.
5. Review the resources that are listed as available for upgrade. When satisfied, click **Approve**.
6. Navigate back to the `Operators → Installed Operators` page to monitor the progress of the upgrade. When complete, the status changes to **Succeeded** and **Up to date**.

5.4. MONITORING UPDATE STATUS

5.4.1. Monitoring OpenShift Virtualization upgrade status

To monitor the status of a OpenShift Virtualization Operator upgrade, watch the cluster service version (CSV) **PHASE**. You can also monitor the CSV conditions in the web console or by running the command provided here.

NOTE

The **PHASE** and conditions values are approximations that are based on available information.

Prerequisites

- Log in to the cluster as a user with the **cluster-admin** role.
• Install the OpenShift CLI (oc).

Procedure

1. Run the following command:

   $ oc get csv -n openshift-cnv

2. Review the output, checking the PHASE field. For example:

   **Example output**

<table>
<thead>
<tr>
<th>VERSION</th>
<th>REPLACES</th>
<th>PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9.0</td>
<td>kubevirt-hyperconverged-operator.v4.8.2</td>
<td>Installing</td>
</tr>
<tr>
<td>4.9.0</td>
<td>kubevirt-hyperconverged-operator.v4.9.0</td>
<td>Replacing</td>
</tr>
</tbody>
</table>

3. Optional: Monitor the aggregated status of all OpenShift Virtualization component conditions by running the following command:

   $ oc get hco -n openshift-cnv kubevirt-hyperconverged
   $ oc get hco -n openshift-cnv kubevirt-hyperconverged
   $ oc get hco -n openshift-cnv kubevirt-hyperconverged
   $ oc get hco -n openshift-cnv kubevirt-hyperconverged

   A successful upgrade results in the following output:

   **Example output**

   - ReconcileComplete: True, Reconcile completed successfully
   - Available: True, Reconcile completed successfully
   - Progressing: False, Reconcile completed successfully
   - Degraded: False, Reconcile completed successfully
   - Upgradeable: True, Reconcile completed successfully

5.4.2. Viewing outdated OpenShift Virtualization workloads

You can view a list of outdated workloads by using the CLI.

   **NOTE**

   If there are outdated virtualization pods in your cluster, the OutdatedVirtualMachineInstanceWorkloads alert fires.

Procedure

• To view a list of outdated virtual machine instances (VMIs), run the following command:

   $ kubectl get vmi -l kubevirt.io/outdatedLauncherImage --all-namespaces

   **NOTE**

   Configure workload updates to ensure that VMIs update automatically.
5.5. ADDITIONAL RESOURCES

- What are Operators?
- Operator Lifecycle Manager concepts and resources
- Cluster service versions (CSVs)
- Virtual machine live migration
- Configuring virtual machine eviction strategy
- Configuring live migration limits and timeouts
CHAPTER 6. ADDITIONAL SECURITY PRIVILEGES GRANTED FOR KUBEVIRT-CONTROLLER AND VIRT-LAUNCHER

The `kubevirt-controller` and virt-launcher pods are granted some SELinux policies and Security Context Constraints privileges that are in addition to typical pod owners. These privileges enable virtual machines to use OpenShift Virtualization features.

6.1. EXTENDED SELINUX POLICIES FOR VIRT-LAUNCHER PODS

The `container_t` SELinux policy for virt-launcher pods is extended with the following rules:

- allow process self (tun_socket (relabelfrom relabelto attach_queue))
- allow process sysfs_t (file (write))
- allow process hugetlbfs_t (dir (add_name create write remove_name rmdir setattr))
- allow process hugetlbfs_t (file (create unlink))

These rules enable the following virtualization features:

- Relabel and attach queues to its own TUN sockets, which is required to support network multi-queue. Multi-queue enables network performance to scale as the number of available vCPUs increases.
- Allows virt-launcher pods to write information to sysfs (`/sys`) files, which is required to enable Single Root I/O Virtualization (SR-IOV).
- Read/write `hugetlbfs` entries, which is required to support huge pages. Huge pages are a method of managing large amounts of memory by increasing the memory page size.

6.2. ADDITIONAL OPENSSHIFT CONTAINER PLATFORM SECURITY CONTEXT CONSTRAINTS AND LINUX CAPABILITIES FOR THE KUBEVIRT-CONTROLLER SERVICE ACCOUNT

Security context constraints (SCCs) control permissions for pods. These permissions include actions that a pod, a collection of containers, can perform and what resources it can access. You can use SCCs to define a set of conditions that a pod must run with to be accepted into the system.

The `kubevirt-controller` is a cluster controller that creates the virt-launcher pods for virtual machines in the cluster. These virt-launcher pods are granted permissions by the `kubevirt-controller` service account.

6.2.1. Additional SCCs granted to the kubevirt-controller service account

The `kubevirt-controller` service account is granted additional SCCs and Linux capabilities so that it can create virt-launcher pods with the appropriate permissions. These extended permissions allow virtual machines to take advantage of OpenShift Virtualization features that are beyond the scope of typical pods.

The `kubevirt-controller` service account is granted the following SCCs:

- `scc.AllowHostDirVolumePlugin = true`
  
  This allows virtual machines to use the hostpath volume plug-in.
**scc.AllowPrivilegedContainer = false**
This ensures the virt-launcher pod is not run as a privileged container.

**scc.AllowedCapabilities = []corev1.Capability{"NET_ADMIN", "NET_RAW", "SYS_NICE"}**
This provides the following additional Linux capabilities **NET_ADMIN**, **NET_RAW**, and **SYS_NICE**.

### 6.2.2. Viewing the SCC and RBAC definitions for the kubevirt-controller

You can view the `SecurityContextConstraints` definition for the `kubevirt-controller` by using the `oc` tool:

```
$ oc get scc kubevirt-controller -o yaml
```

You can view the RBAC definition for the `kubevirt-controller` clusterrole by using the `oc` tool:

```
$ oc get clusterrole kubevirt-controller -o yaml
```

### 6.3. ADDITIONAL RESOURCES


- The `capabilities` man page has more information on the Linux capabilities.

- The `sysfs(5)` man page has more information on sysfs.

- The OpenShift Container Platform Authentication guide has more information on [Security Context Constraints](https://docs.openshift.com/container-platform/4.10/virtualization/security.html).
CHAPTER 7. USING THE CLI TOOLS

The two primary CLI tools used for managing resources in the cluster are:

- The OpenShift Virtualization \texttt{virtctl} client
- The OpenShift Container Platform \texttt{oc} client

7.1. PREREQUISITES

- You must enable the \texttt{virtctl} client.

7.2. OPENSHEFT CONTAINER PLATFORM CLIENT COMMANDS

The OpenShift Container Platform \texttt{oc} client is a command-line utility for managing OpenShift Container Platform resources, including the \texttt{VirtualMachine (vm)} and \texttt{VirtualMachineInstance (vmi)} object types.

\textbf{NOTE}

You can use the \texttt{-n <namespace>} flag to specify a different project.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|}
\hline
\textbf{Command} & \textbf{Description} \\
\hline
\texttt{oc login -u <user\_name>} & Log in to the OpenShift Container Platform cluster as \texttt{<user\_name>}. \\
\hline
\texttt{oc get <object\_type>} & Display a list of objects for the specified object type in the current project. \\
\hline
\texttt{oc describe <object\_type> <resource\_name>} & Display details of the specific resource in the current project. \\
\hline
\texttt{oc create -f <object\_config>} & Create a resource in the current project from a file name or from stdin. \\
\hline
\texttt{oc edit <object\_type> <resource\_name>} & Edit a resource in the current project. \\
\hline
\texttt{oc delete <object\_type> <resource\_name>} & Delete a resource in the current project. \\
\hline
\end{tabular}
\end{table}

For more comprehensive information on \texttt{oc} client commands, see the OpenShift Container Platform CLI tools documentation.

7.3. VIRTCTL CLIENT COMMANDS

The \texttt{virtctl} client is a command-line utility for managing OpenShift Virtualization resources.
To view a list of `virtctl` commands, run the following command:

```
$ virtctl help
```

To view a list of options that you can use with a specific command, run it with the `-h` or `--help` flag. For example:

```
$ virtctl image-upload -h
```

To view a list of global command options that you can use with any `virtctl` command, run the following command:

```
$ virtctl options
```

The following table contains the `virtctl` commands used throughout the OpenShift Virtualization documentation.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>virtctl start &lt;vm_name&gt;</code></td>
<td>Start a virtual machine.</td>
</tr>
<tr>
<td><code>virtctl stop &lt;vm_name&gt;</code></td>
<td>Stop a virtual machine.</td>
</tr>
<tr>
<td>`virtctl pause vm</td>
<td>vmi &lt;object_name&gt;`</td>
</tr>
<tr>
<td>`virtctl unpause vm</td>
<td>vmi &lt;object_name&gt;`</td>
</tr>
<tr>
<td><code>virtctl migrate &lt;vm_name&gt;</code></td>
<td>Migrate a virtual machine.</td>
</tr>
<tr>
<td><code>virtctl restart &lt;vm_name&gt;</code></td>
<td>Restart a virtual machine.</td>
</tr>
<tr>
<td><code>virtctl expose &lt;vm_name&gt;</code></td>
<td>Create a service that forwards a designated port of a virtual machine or virtual machine instance and expose the service on the specified port of the node.</td>
</tr>
<tr>
<td><code>virtctl console &lt;vmi_name&gt;</code></td>
<td>Connect to a serial console of a virtual machine instance.</td>
</tr>
<tr>
<td><code>virtctl vnc --kubeconfig=$KUBECONFIG &lt;vmi_name&gt;</code></td>
<td>Open a VNC (Virtual Network Client) connection to a virtual machine instance. Access the graphical console of a virtual machine instance through a VNC which requires a remote viewer on your local machine.</td>
</tr>
<tr>
<td><code>virtctl vnc --kubeconfig=$KUBECONFIG --proxy-only=true &lt;vmi-name&gt;</code></td>
<td>Display the port number and connect manually to the virtual machine instance by using any viewer through the VNC connection.</td>
</tr>
</tbody>
</table>
## 7.4. Creating a Container Using Virtctl Guestfs

You can use the `virtctl guestfs` command to deploy an interactive container with `libguestfs-tools` and a persistent volume claim (PVC) attached to it.

### Procedure

- To deploy a container with `libguestfs-tools`, mount the PVC, and attach a shell to it, run the following command:

  ```bash
  $ virtctl guestfs -n <namespace> <pvc_name>  
  ```

  The PVC name is a required argument. If you do not include it, an error message appears.

## 7.5. Libguestfs Tools and Virtctl Guestfs

`Libguestfs` tools help you access and modify virtual machine (VM) disk images. You can use `libguestfs` tools to view and edit files in a guest, clone and build virtual machines, and format and resize disks.

You can also use the `virtctl guestfs` command and its sub-commands to modify, inspect, and debug VM disks on a PVC. To see a complete list of possible sub-commands, enter `virt-` on the command line and press the Tab key. For example:
### Command Description

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>virt-edit -a /dev/vda /etc/motd</code></td>
<td>Edit a file interactively in your terminal.</td>
</tr>
<tr>
<td><code>virt-customize -a /dev/vda --ssh-inject root:string:&lt;public key example&gt;</code></td>
<td>Inject an ssh key into the guest and create a login.</td>
</tr>
<tr>
<td><code>virt-df -a /dev/vda -h</code></td>
<td>See how much disk space is used by a VM.</td>
</tr>
<tr>
<td><code>virt-customize -a /dev/vda --run-command 'rpm -qa &gt; /rpm-list'</code></td>
<td>See the full list of all RPMs installed on a guest by creating an output file containing the full list.</td>
</tr>
<tr>
<td><code>virt-cat -a /dev/vda /rpm-list</code></td>
<td>Display the output file list of all RPMs created using the <code>virt-customize -a /dev/vda --run-command 'rpm -qa &gt; /rpm-list'</code> command in your terminal.</td>
</tr>
<tr>
<td><code>virt-sysprep -a /dev/vda</code></td>
<td>Seal a virtual machine disk image to be used as a template.</td>
</tr>
</tbody>
</table>

By default, `virtctl guestfs` creates a session with everything needed to manage a VM disk. However, the command also supports several flag options if you want to customize the behavior:

### Flag Option Description

<table>
<thead>
<tr>
<th>Flag Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--h</code> or <code>--help</code></td>
<td>Provides help for <code>guestfs</code>.</td>
</tr>
<tr>
<td><code>-n &lt;namespace&gt;</code> option with a <code>&lt;pvc_name&gt;</code> argument</td>
<td>To use a PVC from a specific namespace.</td>
</tr>
<tr>
<td><code>--image string</code></td>
<td>Lists the <code>libguestfs-tools</code> container image.</td>
</tr>
</tbody>
</table>

- If you do not use the `-n <namespace>` option, your current project is used. To change projects, use `oc project <namespace>`. |
- If you do not include a `<pvc_name>` argument, an error message appears. |
- You can configure the container to use a custom image by using the `--image` option.
Indicates that `kvm` is used by the `libguestfs-tools` container.

By default, `virtctl guestfs` sets up `kvm` for the interactive container, which greatly speeds up the `libguestfs-tools` execution because it uses QEMU.

If a cluster does not have any `kvm` supporting nodes, you must disable `kvm` by setting the option `--kvm=false`.

If not set, the `libguestfs-tools` pod remains pending because it cannot be scheduled on any node.

---

<table>
<thead>
<tr>
<th>Flag Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--kvm</code></td>
<td>Indicates that <code>kvm</code> is used by the <code>libguestfs-tools</code> container.</td>
</tr>
<tr>
<td></td>
<td>By default, <code>virtctl guestfs</code> sets up <code>kvm</code> for the interactive container, which greatly speeds up the <code>libguestfs-tools</code> execution because it uses QEMU.</td>
</tr>
<tr>
<td></td>
<td>If a cluster does not have any <code>kvm</code> supporting nodes, you must disable <code>kvm</code> by setting the option <code>--kvm=false</code>.</td>
</tr>
<tr>
<td></td>
<td>If not set, the <code>libguestfs-tools</code> pod remains pending because it cannot be scheduled on any node.</td>
</tr>
<tr>
<td><code>--pull-policy string</code></td>
<td>Shows the pull policy for the <code>libguestfs</code> image.</td>
</tr>
<tr>
<td></td>
<td>You can also overwrite the image’s pull policy by setting the <code>pull-policy</code> option.</td>
</tr>
</tbody>
</table>

The command also checks if a PVC is in use by another pod, in which case an error message appears. However, once the `libguestfs-tools` process starts, the setup cannot avoid a new pod using the same PVC. You must verify that there are no active `virtctl guestfs` pods before starting the VM that accesses the same PVC.

NOTE

The `virtctl guestfs` command accepts only a single PVC attached to the interactive pod.

7.6. ADDITIONAL RESOURCES

- Libguestfs: tools for accessing and modifying virtual machine disk images.
CHAPTER 8. VIRTUAL MACHINES

8.1. CREATING VIRTUAL MACHINES

Use one of these procedures to create a virtual machine:

- Quick Start guided tour
- Running the wizard
- Pasting a pre-configured YAML file with the virtual machine wizard
- Using the CLI

**WARNING**
Do not create virtual machines in `openshift-*` namespaces. Instead, create a new namespace or use an existing namespace without the `openshift` prefix.

When you create virtual machines from the web console, select a virtual machine template that is configured with a boot source. Virtual machine templates with a boot source are labeled as **Available boot source** or they display a customized label text. Using templates with an available boot source expedites the process of creating virtual machines.

Templates without a boot source are labeled as **Boot source required**. You can use these templates if you complete the steps for adding a boot source to the virtual machine.

**IMPORTANT**
Due to differences in storage behavior, some virtual machine templates are incompatible with SNO. To ensure compatibility, do not set the `evictionStrategy` field for any templates or virtual machines that use data volumes or storage profiles.

8.1.1. Using a Quick Start to create a virtual machine

The web console provides Quick Starts with instructional guided tours for creating virtual machines. You can access the Quick Starts catalog by selecting the Help menu in the Administrator perspective to view the Quick Starts catalog. When you click on a Quick Start tile and begin the tour, the system guides you through the process.

Tasks in a Quick Start begin with selecting a Red Hat template. Then, you can add a boot source and import the operating system image. Finally, you can save the custom template and use it to create a virtual machine.

Quick Start tours for creating virtual machines include the following:

- Creating a Red Hat Enterprise Linux virtual machine
- Creating a Windows 10 virtual machine
• Importing a VMWare virtual machine

Prerequisites

• Access to the website where you can download the URL link for the operating system image.

Procedure

1. In the web console, select Quick Starts from the Help menu.

2. Click on a tile in the Quick Starts catalog. For example: Creating a Red Hat Linux Enterprise Linux virtual machine.

3. Follow the instructions in the guided tour and complete the tasks for importing an operating system image and creating a virtual machine. The Virtual Machines tab displays the virtual machine.

8.1.2. Running the virtual machine wizard to create a virtual machine

The web console features a wizard that guides you through the process of selecting a virtual machine template and creating a virtual machine. Red Hat virtual machine templates are preconfigured with an operating system image, default settings for the operating system, flavor (CPU and memory), and workload type (server). When templates are configured with a boot source, they are labeled with a customized label text or the default label text Available boot source. These templates are then ready to be used for creating virtual machines.

You can select a template from the list of preconfigured templates, review the settings, and create a virtual machine in the Create virtual machine from template wizard. If you choose to customize your virtual machine, the wizard guides you through the General, Networking, Storage, Advanced, and Review steps. All required fields displayed by the wizard are marked by a *.

Create network interface controllers (NICs) and storage disks later and attach them to virtual machines.

Procedure

1. Click Workloads → Virtualization from the side menu.

2. From the Virtual Machines tab or the Templates tab, click Create and select Virtual Machine with Wizard.

3. Select a template that is configured with a boot source.

4. Click Next to go to the Review and create step.

5. Clear the Start this virtual machine after creation checkbox if you do not want to start the virtual machine now.

6. Click Create virtual machine and exit the wizard or continue with the wizard to customize the virtual machine.

7. Click Customize virtual machine to go to the General step.
   a. Optional: Edit the Name field to specify a custom name for the virtual machine.
   b. Optional: In the Description field, add a description.
8. Click **Next** to go to the **Networking** step. A **nic0** NIC is attached by default.
   
a. Optional: Click **Add Network Interface** to create additional NICs.

b. Optional: You can remove any or all NICs by clicking the Options menu and selecting **Delete**. A virtual machine does not need a NIC attached to be created. You can create NICs after the virtual machine has been created.

9. Click **Next** to go to the **Storage** step.
   
a. Optional: Click **Add Disk** to create additional disks. These disks can be removed by clicking the Options menu and selecting **Delete**.

b. Optional: Click the Options menu to edit the disk and save your changes.

10. Click **Next** to go to the **Advanced** step and choose one of the following options:
   
a. If you selected a Linux template to create the VM, review the details for **Cloud-init** and configure SSH access.

   **NOTE**
   
   Statically inject an SSH key by using the custom script in cloud-init or in the wizard. This allows you to securely and remotely manage virtual machines and manage and transfer information. This step is strongly recommended to secure your VM.

b. If you selected a Windows template to create the VM, use the **SysPrep** section to upload answer files in XML format for automated Windows setup.

11. Click **Next** to go to the **Review** step and review the settings for the virtual machine.

12. Click **Create Virtual Machine**

13. Click **See virtual machine details** to view the **Overview** for this virtual machine. The virtual machine is listed in the **Virtual Machines** tab.

Refer to the virtual machine wizard fields section when running the web console wizard.

**8.1.2.1. Virtual machine wizard fields**

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenShift Container Platform 4.10 Virtualization</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td>The name can contain lowercase letters (a-z), numbers (0-9), and hyphens (-), up to a maximum of 253 characters. The first and last characters must be alphanumeric. The name must not contain uppercase letters, spaces, periods (.), or special characters.</td>
</tr>
<tr>
<td>Description</td>
<td></td>
<td>Optional description field.</td>
</tr>
<tr>
<td>Operating System</td>
<td></td>
<td>The operating system that is selected for the virtual machine in the template. You cannot edit this field when creating a virtual machine from a template.</td>
</tr>
<tr>
<td>Boot Source</td>
<td>Import via URL (creates PVC)</td>
<td>Import content from an image available from an HTTP or S3 endpoint. Example: Obtaining a URL link from the web page with the operating system image.</td>
</tr>
<tr>
<td></td>
<td>Clone existing PVC (creates PVC)</td>
<td>Select an existent persistent volume claim available on the cluster and clone it.</td>
</tr>
<tr>
<td></td>
<td>Import via Registry (creates PVC)</td>
<td>Provision virtual machine from a bootable operating system container located in a registry accessible from the cluster. Example: kubevirt/cirros-registry-disk-demo.</td>
</tr>
<tr>
<td></td>
<td>PXE (network boot – adds network interface)</td>
<td>Boot an operating system from a server on the network. Requires a PXE bootable network attachment definition.</td>
</tr>
<tr>
<td>Persistent Volume Claim project</td>
<td></td>
<td>Project name that you want to use for cloning the PVC.</td>
</tr>
<tr>
<td>Persistent Volume Claim name</td>
<td></td>
<td>PVC name that should apply to this virtual machine template if you are cloning an existing PVC.</td>
</tr>
<tr>
<td>Name</td>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mount this as a CD-ROM boot source</td>
<td></td>
<td>A CD-ROM requires an additional disk for installing the operating system. Select the checkbox to add a disk and customize it later.</td>
</tr>
<tr>
<td>Flavor</td>
<td>Tiny, Small, Medium, Large, Custom</td>
<td>Presets the amount of CPU and memory in a virtual machine template with predefined values that are allocated to the virtual machine, depending on the operating system associated with that template. If you choose a default template, you can override the <code>cpus</code> and <code>memsize</code> values in the template using custom values to create a custom template. Alternatively, you can create a custom template by modifying the <code>cpus</code> and <code>memsize</code> values in the Details tab on the Workloads → Virtualization page.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workload Type</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop</td>
<td></td>
<td>A virtual machine configuration for use on a desktop. Ideal for consumption on a small scale. Recommended for use with the web console. Use this template class or the Server template class to prioritize VM density over guaranteed VM performance.</td>
</tr>
<tr>
<td>Server</td>
<td></td>
<td>Balances performance and it is compatible with a wide range of server workloads. Use this template class or the Desktop template class to prioritize VM density over guaranteed VM performance.</td>
</tr>
<tr>
<td>High-Performance (requires CPU Manager)</td>
<td></td>
<td>A virtual machine configuration that is optimized for high-performance workloads. Use this template class to prioritize guaranteed VM performance over VM density.</td>
</tr>
</tbody>
</table>
Enable the **CPU Manager** to use the high-performance workload profile.

### 8.1.2.2. Networking fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name for the network interface controller.</td>
</tr>
<tr>
<td>Model</td>
<td>Indicates the model of the network interface controller. Supported values are <strong>e1000e</strong> and <strong>virtio</strong>.</td>
</tr>
<tr>
<td>Network</td>
<td>List of available network attachment definitions.</td>
</tr>
<tr>
<td>Type</td>
<td>List of available binding methods. For the default pod network, <strong>masquerade</strong> is the only recommended binding method. For secondary networks, use the <strong>bridge</strong> binding method. The <strong>masquerade</strong> method is not supported for non-default networks. Select <strong>SR-IOV</strong> if you configured an SR-IOV network device and defined that network in the namespace.</td>
</tr>
<tr>
<td>MAC Address</td>
<td>MAC address for the network interface controller. If a MAC address is not specified, one is assigned automatically.</td>
</tr>
</tbody>
</table>

### 8.1.2.3. Storage fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Selection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Blank (creates PVC)</td>
<td>Create an empty disk.</td>
</tr>
<tr>
<td></td>
<td>Import via URL (creates PVC)</td>
<td>Import content via URL (HTTP or S3 endpoint).</td>
</tr>
<tr>
<td></td>
<td>Use an existing PVC</td>
<td>Use a PVC that is already available in the cluster.</td>
</tr>
</tbody>
</table>
### Advanced storage settings

<table>
<thead>
<tr>
<th>Name</th>
<th>Selection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clone existing PVC</td>
<td>Select an existing PVC available in the cluster and clone it.</td>
<td></td>
</tr>
<tr>
<td>Import via Registry</td>
<td>Import content via container registry.</td>
<td></td>
</tr>
<tr>
<td>Container (ephemeral)</td>
<td>Upload content from a container located in a registry accessible from the cluster. The container disk should be used only for read-only filesystems such as CD-ROMs or temporary virtual machines.</td>
<td></td>
</tr>
</tbody>
</table>

#### Name

Name of the disk. The name can contain lowercase letters (a-z), numbers (0-9), hyphens (-), and periods (.), up to a maximum of 253 characters. The first and last characters must be alphanumeric. The name must not contain uppercase letters, spaces, or special characters.

#### Size

Size of the disk in GiB.

#### Type

Type of disk. Example: Disk or CD-ROM

#### Interface

Type of disk device. Supported interfaces are virtIO, SATA, and SCSI.

#### Storage Class

The storage class that is used to create the disk.

#### Advanced → Volume Mode

**NOTE**

Default values are used from the storage profile.

Defines whether the persistent volume uses a formatted file system or raw block state. Default is Filesystem.
### 8.1.2.4. Cloud-init fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hostname</td>
<td></td>
<td>Sets a specific hostname for the virtual machine.</td>
</tr>
<tr>
<td>Authorized SSH Keys</td>
<td></td>
<td>The user’s public key that is copied to <code>~/.ssh/authorized_keys</code> on the virtual machine.</td>
</tr>
<tr>
<td>Custom script</td>
<td></td>
<td>Replaces other options with a field in which you paste a custom cloud-init script.</td>
</tr>
</tbody>
</table>

To configure storage class defaults, use storage profiles. For more information, see [Customizing the storage profile](#).

### 8.1.3. Pasting in a pre-configured YAML file to create a virtual machine

Create a virtual machine by writing or pasting a YAML configuration file. A valid example virtual machine configuration is provided by default whenever you open the YAML edit screen.

If your YAML configuration is invalid when you click Create, an error message indicates the parameter in which the error occurs. Only one error is shown at a time.

**NOTE**

Navigating away from the YAML screen while editing cancels any changes to the configuration you have made.

**Procedure**

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Click Create and select Virtual Machine With YAML.
4. Write or paste your virtual machine configuration in the editable window.
   a. Alternatively, use the example virtual machine provided by default in the YAML screen.
5. Optional: Click **Download** to download the YAML configuration file in its present state.

6. Click **Create** to create the virtual machine.

The virtual machine is listed in the **Virtual Machines** tab.

### 8.1.4. Using the CLI to create a virtual machine

**Procedure**

The **spec** object of the virtual machine configuration file references the virtual machine settings, such as the number of cores and the amount of memory, the disk type, and the volumes to use.

1. Attach the virtual machine disk to the virtual machine by referencing the relevant PVC **claimName** as a volume.

2. To create a virtual machine with the OpenShift Container Platform client, run this command:

   ```bash
   $ oc create -f <vm.yaml>
   ```

3. Since virtual machines are created in a **Stopped** state, run a virtual machine instance by starting it.

   **NOTE**

   A **ReplicaSet**'s purpose is often used to guarantee the availability of a specified number of identical pods. ReplicaSet is not currently supported in OpenShift Virtualization.

**Table 8.1. Domain settings**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cores</td>
<td>The number of cores inside the virtual machine. Must be a value greater than or equal to 1.</td>
</tr>
<tr>
<td>Memory</td>
<td>The amount of RAM that is allocated to the virtual machine by the node. Specify a value in <strong>M</strong> for Megabyte or <strong>Gi</strong> for Gigabyte.</td>
</tr>
<tr>
<td>Disks</td>
<td>The name of the volume that is referenced. Must match the name of a volume.</td>
</tr>
</tbody>
</table>

**Table 8.2. Volume settings**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>The name of the volume, which must be a DNS label and unique within the virtual machine.</td>
</tr>
</tbody>
</table>
### PersistentVolumeClaim

The PVC to attach to the virtual machine. The `claimName` of the PVC must be in the same project as the virtual machine.

### 8.1.5. Virtual machine storage volume types

<table>
<thead>
<tr>
<th>Storage volume type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ephemeral</td>
<td>A local copy-on-write (COW) image that uses a network volume as a read-only backing store. The backing volume must be a <code>PersistentVolumeClaim</code>. The ephemeral image is created when the virtual machine starts and stores all writes locally. The ephemeral image is discarded when the virtual machine is stopped, restarted, or deleted. The backing volume (PVC) is not mutated in any way.</td>
</tr>
<tr>
<td>persistentVolumeClaim</td>
<td>Attaches an available PV to a virtual machine. Attaching a PV allows for the virtual machine data to persist between sessions. Importing an existing virtual machine disk into a PVC by using CDI and attaching the PVC to a virtual machine instance is the recommended method for importing existing virtual machines into OpenShift Container Platform. There are some requirements for the disk to be used within a PVC.</td>
</tr>
<tr>
<td>dataVolume</td>
<td>Data volumes build on the <code>persistentVolumeClaim</code> disk type by managing the process of preparing the virtual machine disk via an import, clone, or upload operation. VMs that use this volume type are guaranteed not to start until the volume is ready. Specify <code>type: dataVolume</code> or <code>type: &quot;&quot;</code>. If you specify any other value for <code>type</code>, such as <code>persistentVolumeClaim</code>, a warning is displayed, and the virtual machine does not start.</td>
</tr>
<tr>
<td>cloudInitNoCloud</td>
<td>Attaches a disk that contains the referenced cloud-init NoCloud data source, providing user data and metadata to the virtual machine. A cloud-init installation is required inside the virtual machine disk.</td>
</tr>
</tbody>
</table>
8.1.6. About RunStrategies for virtual machines

A RunStrategy for virtual machines determines a virtual machine instance’s (VMI) behavior, depending on a series of conditions. The `spec.runStrategy` setting exists in the virtual machine configuration process as an alternative to the `spec.running` setting. The `spec.runStrategy` setting allows greater flexibility for how VMIs are created and managed, in contrast to the `spec.running` setting with only true or false responses. However, the two settings are mutually exclusive. Only either `spec.running` or `spec.runStrategy` can be used. An error occurs if both are used.

There are four defined RunStrategies.

**Always**

A VMI is always present when a virtual machine is created. A new VMI is created if the original stops for any reason, which is the same behavior as `spec.running: true`.

**RerunOnFailure**

A VMI is re-created if the previous instance fails due to an error. The instance is not re-created if the virtual machine stops or is restarted from the web console. The empty disk is used to store application dependencies and data that otherwise exceeds the limited temporary file system of an ephemeral disk.

The disk capacity size must also be provided.

<table>
<thead>
<tr>
<th>Storage volume type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>containerDisk</td>
<td>References an image, such as a virtual machine disk, that is stored in the container image registry. The image is pulled from the registry and attached to the virtual machine as a disk when the virtual machine is launched.</td>
</tr>
<tr>
<td></td>
<td>A containerDisk volume is not limited to a single virtual machine and is useful for creating large numbers of virtual machine clones that do not require persistent storage.</td>
</tr>
<tr>
<td></td>
<td>Only RAW and QCOW2 formats are supported disk types for the container image registry. QCOW2 is recommended for reduced image size.</td>
</tr>
<tr>
<td></td>
<td><strong>NOTE</strong></td>
</tr>
<tr>
<td></td>
<td>A containerDisk volume is ephemeral. It is discarded when the virtual machine is stopped, restarted, or deleted. A containerDisk volume is useful for read-only file systems such as CD-ROMs or for disposable virtual machines.</td>
</tr>
<tr>
<td>emptyDisk</td>
<td>Creates an additional sparse QCOW2 disk that is tied to the life-cycle of the virtual machine interface. The data survives guest-initiated reboots in the virtual machine but is discarded when the virtual machine stops or is restarted from the web console. The empty disk is used to store application dependencies and data that otherwise exceeds the limited temporary file system of an ephemeral disk.</td>
</tr>
<tr>
<td></td>
<td>The disk capacity size must also be provided.</td>
</tr>
</tbody>
</table>
A VMI is re-created if the previous instance fails due to an error. The instance is not re-created if the virtual machine stops successfully, such as when it shuts down.

**Manual**

The `start`, `stop`, and `restart` `virtctl` client commands can be used to control the VMI’s state and existence.

**Halted**

No VMI is present when a virtual machine is created, which is the same behavior as `spec.running: false`.

Different combinations of the `start`, `stop` and `restart` `virtctl` commands affect which `RunStrategy` is used.

The following table follows a VM’s transition from different states. The first column shows the VM’s initial `RunStrategy`. Each additional column shows a `virtctl` command and the new `RunStrategy` after that command is run.

<table>
<thead>
<tr>
<th>Initial RunStrategy</th>
<th>start</th>
<th>stop</th>
<th>restart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>-</td>
<td>Halted</td>
<td>Always</td>
</tr>
<tr>
<td>RerunOnFailure</td>
<td>-</td>
<td>Halted</td>
<td>RerunOnFailure</td>
</tr>
<tr>
<td>Halted</td>
<td>Always</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**NOTE**

In OpenShift Virtualization clusters installed using installer-provisioned infrastructure, when a node fails the MachineHealthCheck and becomes unavailable to the cluster, VMs with a RunStrategy of `Always` or `RerunOnFailure` are rescheduled on a new node.

apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
  RunStrategy: Always
1
template:
...

1 The VMI’s current `RunStrategy` setting.

## 8.1.7. Additional resources

- The `VirtualMachineSpec` definition in the [KubeVirt v0.49.0 API Reference](https://kubevirt.io/v0.49.0/api-reference/index.html) provides broader context for the parameters and hierarchy of the virtual machine specification.
NOTE

The KubeVirt API Reference is the upstream project reference and might contain parameters that are not supported in OpenShift Virtualization.

- See Prepare a container disk before adding it to a virtual machine as a `containerDisk` volume.
- See Deploying machine health checks for further details on deploying and enabling machine health checks.
- See Installer-provisioned infrastructure overview for further details on installer-provisioned infrastructure.
- See Customizing the storage profile

8.2. EDITING VIRTUAL MACHINES

You can update a virtual machine configuration using either the YAML editor in the web console or the OpenShift CLI on the command line. You can also update a subset of the parameters in the Virtual Machine Details screen.

8.2.1. Editing a virtual machine in the web console

Edit select values of a virtual machine in the web console by clicking the pencil icon next to the relevant field. Other values can be edited using the CLI.

Labels and annotations are editable for both preconfigured Red Hat templates and your custom virtual machine templates. All other values are editable only for custom virtual machine templates that users have created using the Red Hat templates or the Create Virtual Machine Template wizard.

Procedure

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine.
4. Click the Details tab.
5. Click the pencil icon to make a field editable.
6. Make the relevant changes and click Save.

NOTE

If the virtual machine is running, changes to Boot Order or Flavor will not take effect until you restart the virtual machine.

You can view pending changes by clicking View Pending Changes on the right side of the relevant field. The Pending Changes banner at the top of the page displays a list of all changes that will be applied when the virtual machine restarts.
8.2.2. Editing a virtual machine YAML configuration using the web console

You can edit the YAML configuration of a virtual machine in the web console. Some parameters cannot be modified. If you click **Save** with an invalid configuration, an error message indicates the parameter that cannot be changed.

If you edit the YAML configuration while the virtual machine is running, changes will not take effect until you restart the virtual machine.

**NOTE**

Navigating away from the YAML screen while editing cancels any changes to the configuration you have made.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.
2. Select a virtual machine.
3. Click the **YAML** tab to display the editable configuration.
4. Optional: You can click **Download** to download the YAML file locally in its current state.
5. Edit the file and click **Save**.

A confirmation message shows that the modification has been successful and includes the updated version number for the object.

8.2.3. Editing a virtual machine YAML configuration using the CLI

Use this procedure to edit a virtual machine YAML configuration using the CLI.

**Prerequisites**

- You configured a virtual machine with a YAML object configuration file.
- You installed the **oc** CLI.

**Procedure**

1. Run the following command to update the virtual machine configuration:

   ```
   $ oc edit <object_type> <object_ID>
   ```

2. Open the object configuration.
3. Edit the YAML.
4. If you edit a running virtual machine, you need to do one of the following:
   - Restart the virtual machine.
   - Run the following command for the new configuration to take effect:
8.2.4. Adding a virtual disk to a virtual machine

Use this procedure to add a virtual disk to a virtual machine.

**Procedure**

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine to open the Virtual Machine Overview screen.
4. Click the Disks tab.
5. In the Add Disk window, specify the Source, Name, Size, Type, Interface, and Storage Class.
   a. Advanced: You can enable preallocation if you use a blank disk source and require maximum write performance when creating data volumes. To do so, select the Enable preallocation checkbox.
   b. Optional: In the Advanced list, specify the Volume Mode and Access Mode for the virtual disk. If you do not specify these parameters, the system uses the default values from the kubevirt-storage-class-defaults config map.
6. Click Add.

**NOTE**

If the virtual machine is running, the new disk is in the pending restart state and will not be attached until you restart the virtual machine.

The Pending Changes banner at the top of the page displays a list of all changes that will be applied when the virtual machine restarts.

To configure storage class defaults, use storage profiles. For more information, see Customizing the storage profile.

### 8.2.4.1. Storage fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Selection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Blank (creates PVC)</td>
<td>Create an empty disk.</td>
</tr>
<tr>
<td></td>
<td>Import via URL (creates PVC)</td>
<td>Import content via URL (HTTP or S3 endpoint).</td>
</tr>
<tr>
<td></td>
<td>Use an existing PVC</td>
<td>Use a PVC that is already available in the cluster.</td>
</tr>
<tr>
<td>Name</td>
<td>Selection</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Clone existing PVC (creates PVC)</td>
<td>Select an existing PVC available in the cluster and clone it.</td>
<td></td>
</tr>
<tr>
<td>Import via Registry (creates PVC)</td>
<td>Import content via container registry.</td>
<td></td>
</tr>
<tr>
<td>Container (ephemeral)</td>
<td>Upload content from a container located in a registry accessible from the cluster. The container disk should be used only for read-only filesystems such as CD-ROMs or temporary virtual machines.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name of the disk. The name can contain lowercase letters (a-z), numbers (0-9), hyphens (-), and periods (.), up to a maximum of 253 characters. The first and last characters must be alphanumeric. The name must not contain uppercase letters, spaces, or special characters.</td>
</tr>
<tr>
<td>Size</td>
<td>Size of the disk in GiB.</td>
</tr>
<tr>
<td>Type</td>
<td>Type of disk. Example: Disk or CD-ROM</td>
</tr>
<tr>
<td>Interface</td>
<td>Type of disk device. Supported interfaces are virtIO, SATA, and SCSI.</td>
</tr>
<tr>
<td>Storage Class</td>
<td>The storage class that is used to create the disk.</td>
</tr>
</tbody>
</table>

**Advanced → Volume Mode**

**NOTE**

Default values are used from the storage profile. Defines whether the persistent volume uses a formatted file system or raw block state. Default is **Filesystem**.

**Advanced storage settings**
8.2.5. Adding a network interface to a virtual machine

Use this procedure to add a network interface to a virtual machine.

Procedure

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine to open the Virtual Machine Overview screen.
4. Click the Network Interfaces tab.
5. Click Add Network Interface.
6. In the Add Network Interface window, specify the Name, Model, Network, Type, and MAC Address of the network interface.
7. Click Add.

**NOTE**

If the virtual machine is running, the new network interface is in the pending restart state and changes will not take effect until you restart the virtual machine.

The Pending Changes banner at the top of the page displays a list of all changes that will be applied when the virtual machine restarts.

### 8.2.5.1. Networking fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name for the network interface controller.</td>
</tr>
<tr>
<td>Model</td>
<td>Indicates the model of the network interface controller. Supported values are e1000e and virtio.</td>
</tr>
<tr>
<td>Network</td>
<td>List of available network attachment definitions.</td>
</tr>
</tbody>
</table>
### Name | Description
--- | ---
Type | List of available binding methods. For the default pod network, **masquerade** is the only recommended binding method. For secondary networks, use the **bridge** binding method. The **masquerade** method is not supported for non-default networks. Select **SR-IOV** if you configured an SR-IOV network device and defined that network in the namespace.
MAC Address | MAC address for the network interface controller. If a MAC address is not specified, one is assigned automatically.

**8.2.6. Editing CD-ROMs for Virtual Machines**

Use the following procedure to edit CD-ROMs for virtual machines.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.
2. Click the **Virtual Machines** tab.
3. Select a virtual machine to open the **Virtual Machine Overview** screen.
4. Click the **Disks** tab.
5. Click the Options menu for the CD-ROM that you want to edit and select **Edit**.
6. In the **Edit CD-ROM** window, edit the fields: **Source**, **Persistent Volume Claim**, **Name**, **Type**, and **Interface**.
7. Click **Save**.

**8.2.7. Additional resources**

- Customizing the storage profile

**8.3. EDITING BOOT ORDER**

You can update the values for a boot order list by using the web console or the CLI.

With **Boot Order** in the **Virtual Machine Overview** page, you can:

- Select a disk or network interface controller (NIC) and add it to the boot order list.
- Edit the order of the disks or NICs in the boot order list.
- Remove a disk or NIC from the boot order list, and return it back to the inventory of bootable sources.

### 8.3.1. Adding items to a boot order list in the web console

Add items to a boot order list by using the web console.

**Procedure**

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine to open the Virtual Machine Overview screen.
4. Click the Details tab.
5. Click the pencil icon that is located on the right side of Boot Order. If a YAML configuration does not exist, or if this is the first time that you are creating a boot order list, the following message displays: No resource selected. VM will attempt to boot from disks by order of appearance in YAML file.
6. Click Add Source and select a bootable disk or network interface controller (NIC) for the virtual machine.
7. Add any additional disks or NICs to the boot order list.
8. Click Save.

**NOTE**

If the virtual machine is running, changes to Boot Order will not take effect until you restart the virtual machine.

You can view pending changes by clicking View Pending Changes on the right side of the Boot Order field. The Pending Changes banner at the top of the page displays a list of all changes that will be applied when the virtual machine restarts.

### 8.3.2. Editing a boot order list in the web console

Edit the boot order list in the web console.

**Procedure**

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine to open the Virtual Machine Overview screen.
4. Click the Details tab.
5. Click the pencil icon that is located on the right side of Boot Order.
6. Choose the appropriate method to move the item in the boot order list:
If you do not use a screen reader, hover over the arrow icon next to the item that you want to move, drag the item up or down, and drop it in a location of your choice.

If you use a screen reader, press the Up Arrow key or Down Arrow key to move the item in the boot order list. Then, press the Tab key to drop the item in a location of your choice.

7. Click Save.

NOTE

If the virtual machine is running, changes to the boot order list will not take effect until you restart the virtual machine.

You can view pending changes by clicking View Pending Changes on the right side of the Boot Order field. The Pending Changes banner at the top of the page displays a list of all changes that will be applied when the virtual machine restarts.

8.3.3. Editing a boot order list in the YAML configuration file

Edit the boot order list in a YAML configuration file by using the CLI.

Procedure

1. Open the YAML configuration file for the virtual machine by running the following command:

   $ oc edit vm example

2. Edit the YAML file and modify the values for the boot order associated with a disk or network interface controller (NIC). For example:

   ```yaml
   disks:
     - bootOrder: 1
       disk:
         bus: virtio
         name: containerdisk
     - disk:
         bus: virtio
         name: cloudinitdisk
     - cdrom:
         bus: virtio
         name: cd-drive-1
   interfaces:
     - bootOrder: 2
       macAddress: '02:96:c4:00:00'
       masquerade: {}
       name: default
   ``

   - The boot order value specified for the disk.
   - The boot order value specified for the network interface controller.

3. Save the YAML file.
4. Click **reload the content** to apply the updated boot order values from the YAML file to the boot order list in the web console.

### 8.3.4. Removing items from a boot order list in the web console

Remove items from a boot order list by using the web console.

**Procedure**

1. Click **Workloads** → **Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** screen.

4. Click the **Details** tab.

5. Click the pencil icon that is located on the right side of **Boot Order**.

6. Click the **Remove** icon next to the item. The item is removed from the boot order list and saved in the list of available boot sources. If you remove all items from the boot order list, the following message displays: **No resource selected. VM will attempt to boot from disks by order of appearance in YAML file.**

**NOTE**

If the virtual machine is running, changes to **Boot Order** will not take effect until you restart the virtual machine.

You can view pending changes by clicking **View Pending Changes** on the right side of the **Boot Order** field. The **Pending Changes** banner at the top of the page displays a list of all changes that will be applied when the virtual machine restarts.

### 8.4. DELETING VIRTUAL MACHINES

You can delete a virtual machine from the web console or by using the **oc** command line interface.

#### 8.4.1. Deleting a virtual machine using the web console

Deleting a virtual machine permanently removes it from the cluster.

**NOTE**

When you delete a virtual machine, the data volume it uses is automatically deleted.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads** → **Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Click the **Options menu** of the virtual machine that you want to delete and select **Delete Virtual Machine**.
Alternatively, click the virtual machine name to open the Virtual Machine Overview screen and click Actions → Delete Virtual Machine.

4. In the confirmation pop-up window, click Delete to permanently delete the virtual machine.

8.4.2. Deleting a virtual machine by using the CLI

You can delete a virtual machine by using the `oc` command line interface (CLI). The `oc` client enables you to perform actions on multiple virtual machines.

**NOTE**

When you delete a virtual machine, the data volume it uses is automatically deleted.

**Prerequisites**

- Identify the name of the virtual machine that you want to delete.

**Procedure**

- Delete the virtual machine by running the following command:

  ```
  $ oc delete vm <vm_name>
  ```

**NOTE**

This command only deletes objects that exist in the current project. Specify the `-n <project_name>` option if the object you want to delete is in a different project or namespace.

8.5. MANAGING VIRTUAL MACHINE INSTANCES

If you have standalone virtual machine instances (VMIs) that were created independently outside of the OpenShift Virtualization environment, you can manage them by using the web console or the command-line interface (CLI).

8.5.1. About virtual machine instances

A virtual machine instance (VMI) is a representation of a running virtual machine (VM). When a VMI is owned by a VM or by another object, you manage it through its owner in the web console or by using the `oc` command-line interface (CLI).

A standalone VMI is created and started independently with a script, through automation, or by using other methods in the CLI. In your environment, you might have standalone VMIs that were developed and started outside of the OpenShift Virtualization environment. You can continue to manage those standalone VMIs by using the CLI. You can also use the web console for specific tasks associated with standalone VMIs:

- List standalone VMIs and their details.
- Edit labels and annotations for a standalone VMI.
- Delete a standalone VMI.
When you delete a VM, the associated VMI is automatically deleted. You delete a standalone VMI directly because it is not owned by VMs or other objects.

NOTE

Before you uninstall OpenShift Virtualization, list and view the standalone VMIs by using the CLI or the web console. Then, delete any outstanding VMIs.

8.5.2. Listing all virtual machine instances using the CLI

You can list all virtual machine instances (VMIs) in your cluster, including standalone VMIs and those owned by virtual machines, by using the `oc` command-line interface (CLI).

Procedure

- List all VMIs by running the following command:

```
$ oc get vmis
```

8.5.3. Listing standalone virtual machine instances using the web console

Using the web console, you can list and view standalone virtual machine instances (VMIs) in your cluster that are not owned by virtual machines (VMs).

NOTE

VMIs that are owned by VMs or other objects are not displayed in the web console. The web console displays only standalone VMIs. If you want to list all VMIs in your cluster, you must use the CLI.

Procedure

- Click Workloads → Virtualization from the side menu. A list of VMs and standalone VMIs displays. You can identify standalone VMIs by the dark colored badges that display next to the virtual machine instance names.

8.5.4. Editing a standalone virtual machine instance using the web console

You can edit annotations and labels for a standalone virtual machine instance (VMI) using the web console. Other items displayed in the Details page for a standalone VMI are not editable.

Procedure

1. Click Workloads → Virtualization from the side menu. A list of virtual machines (VMs) and standalone VMIs displays.

2. Click the name of a standalone VMI to open the Virtual Machine Instance Overview screen.

3. Click the Details tab.

4. Click the pencil icon that is located on the right side of Annotations.

5. Make the relevant changes and click Save.
NOTE

To edit labels for a standalone VMI, click Actions and select Edit Labels. Make the relevant changes and click Save.

8.5.5. Deleting a standalone virtual machine instance using the CLI

You can delete a standalone virtual machine instance (VMI) by using the oc command-line interface (CLI).

Prerequisites

- Identify the name of the VMI that you want to delete.

Procedure

- Delete the VMI by running the following command:

  $ oc delete vmi <vmi_name>

8.5.6. Deleting a standalone virtual machine instance using the web console

Delete a standalone virtual machine instance (VMI) from the web console.

Procedure

1. In the OpenShift Container Platform web console, click Workloads → Virtualization from the side menu.

2. Click the ⋮ button of the standalone virtual machine instance (VMI) that you want to delete and select Delete Virtual Machine Instance

   - Alternatively, click the name of the standalone VMI. The Virtual Machine Instance Overview page displays.

3. Select Actions → Delete Virtual Machine Instance

4. In the confirmation pop-up window, click Delete to permanently delete the standalone VMI.

8.6. CONTROLLING VIRTUAL MACHINE STATES

You can stop, start, restart, and unpause virtual machines from the web console.

NOTE

To control virtual machines from the command-line interface (CLI), use the virtctl client.

8.6.1. Starting a virtual machine

You can start a virtual machine from the web console.

Procedure
1. Click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Find the row that contains the virtual machine that you want to start.

4. Navigate to the appropriate menu for your use case:
   - To stay on this page, where you can perform actions on multiple virtual machines:
     a. Click the Options menu located at the far right end of the row.
   - To view comprehensive information about the selected virtual machine before you start it:
     a. Access the **Virtual Machine Overview** screen by clicking the name of the virtual machine.
     b. Click **Actions**.

5. Select **Start Virtual Machine**

6. In the confirmation window, click **Start** to start the virtual machine.

**NOTE**

When you start virtual machine that is provisioned from a **URL** source for the first time, the virtual machine has a status of **Importing** while OpenShift Virtualization imports the container from the URL endpoint. Depending on the size of the image, this process might take several minutes.

### 8.6.2. Restarting a virtual machine

You can restart a running virtual machine from the web console.

**IMPORTANT**

To avoid errors, do not restart a virtual machine while it has a status of **Importing**.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Find the row that contains the virtual machine that you want to restart.

4. Navigate to the appropriate menu for your use case:
   - To stay on this page, where you can perform actions on multiple virtual machines:
     a. Click the Options menu located at the far right end of the row.
   - To view comprehensive information about the selected virtual machine before you restart it:
a. Access the Virtual Machine Overview screen by clicking the name of the virtual machine.

b. Click Actions.

5. Select Restart Virtual Machine

6. In the confirmation window, click Restart to restart the virtual machine.

8.6.3. Stopping a virtual machine

You can stop a virtual machine from the web console.

Procedure

1. Click Workloads → Virtualization from the side menu.

2. Click the Virtual Machines tab.

3. Find the row that contains the virtual machine that you want to stop.

4. Navigate to the appropriate menu for your use case:

   - To stay on this page, where you can perform actions on multiple virtual machines:
     a. Click the Options menu located at the far right end of the row.

   - To view comprehensive information about the selected virtual machine before you stop it:
     a. Access the Virtual Machine Overview screen by clicking the name of the virtual machine.
     b. Click Actions.

5. Select Stop Virtual Machine

6. In the confirmation window, click Stop to stop the virtual machine.

8.6.4. Unpausing a virtual machine

You can unpause a paused virtual machine from the web console.

Prerequisites

- At least one of your virtual machines must have a status of Paused.

NOTE

You can pause virtual machines by using the virtctl client.

Procedure

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.

3. Find the row that contains the virtual machine that you want to unpause.

4. Navigate to the appropriate menu for your use case:
   - To stay on this page, where you can perform actions on multiple virtual machines:
     a. In the Status column, clickPaused.
   - To view comprehensive information about the selected virtual machine before you unpause it:
     a. Access the Virtual Machine Overview screen by clicking the name of the virtual machine.
     b. Click the pencil icon that is located on the right side of Status.

5. In the confirmation window, click Unpause to unpause the virtual machine.

8.7. ACCESSING VIRTUAL MACHINE CONSOLES

OpenShift Virtualization provides different virtual machine consoles that you can use to accomplish different product tasks. You can access these consoles through the web console and by using CLI commands.

8.7.1. About virtual machine console sessions

You can connect to the VNC and serial consoles of a running virtual machine from the Console tab on the Virtual Machine Details page of the web console.

The VNC Console opens by default when you navigate to the Console tab. You can open a connection to the serial console by clicking the VNC Console drop-down list and selecting Serial Console.

Console sessions remain active in the background unless they are disconnected. To ensure that only one console session is open at a time, click the Disconnect before switching check box before switching consoles.

You can open the active console session in a detached window by clicking Open Console in New Window or by clicking Actions → Open Console.

Options for the VNC Console

- Send key combinations to the virtual machine by clicking Send Key.

Options for the Serial Console

- Manually disconnect the Serial Console session from the virtual machine by clicking Disconnect.
- Manually open a Serial Console session to the virtual machine by clicking Reconnect.

8.7.2. Connecting to the virtual machine with the web console

8.7.2.1. Connecting to the terminal
You can connect to a virtual machine by using the web console.

**Procedure**

1. Ensure you are in the correct project. If not, click the **Project** list and select the appropriate project.

2. Click **Workloads → Virtualization** from the side menu.

3. Click the **Virtual Machines** tab.

4. Select a virtual machine to open the **Virtual Machine Overview** screen.

5. In the **Details** tab, click the **virt-launcher-<vm-name>** pod.

6. Click the **Terminal** tab. If the terminal is blank, select the terminal and press any key to initiate connection.

**8.7.2.2. Connecting to the serial console**

Connect to the **Serial Console** of a running virtual machine from the **Console** tab in the **Virtual Machine Overview** screen of the web console.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** page.

4. Click **Console**. The VNC console opens by default.

5. Click the **VNC Console** drop-down list and select **Serial Console**.

6. Optional: Open the serial console in a separate window by clicking **Open Console in New Window**.

**8.7.2.3. Connecting to the VNC console**

Connect to the VNC console of a running virtual machine from the **Console** tab in the **Virtual Machine Overview** screen of the web console.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** page.

4. Click the **Console** tab. The VNC console opens by default.

5. Optional: Open the VNC console in a separate window by clicking **Open Console in New Window**.
8.7.2.4. Connecting to the RDP console

The desktop viewer console, which utilizes the Remote Desktop Protocol (RDP), provides a better console experience for connecting to Windows virtual machines.

To connect to a Windows virtual machine with RDP, download the `console.rdp` file for the virtual machine from the Consoles tab in the Virtual Machine Details screen of the web console and supply it to your preferred RDP client.

**Prerequisites**

- A running Windows virtual machine with the QEMU guest agent installed. The `qemu-guest-agent` is included in the VirtIO drivers.
- A layer-2 NIC attached to the virtual machine.
- An RDP client installed on a machine on the same network as the Windows virtual machine.

**Procedure**

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
4. Click the Console tab.
5. In the Console list, select Desktop Viewer.
6. In the Network Interface list, select the layer-2 NIC.
7. Click Launch Remote Desktop to download the `console.rdp` file.
8. Open an RDP client and reference the `console.rdp` file. For example, using `remmina`:
   ```
   $ remmina --connect /path/to/console.rdp
   ```
9. Enter the Administrator user name and password to connect to the Windows virtual machine.

8.7.3. Accessing virtual machine consoles by using CLI commands

8.7.3.1. Accessing a virtual machine instance via SSH

You can use SSH to access a virtual machine (VM) after you expose port 22 on it.

The `virtctl expose` command forwards a virtual machine instance (VMI) port to a node port and creates a service for enabled access. The following example creates the `fedora-vm-ssh` service that forwards traffic from a specific port of cluster nodes to port 22 of the `<fedora-vm>` virtual machine.

**Prerequisites**

- You must be in the same project as the VMI.
The VMI you want to access must be connected to the default pod network by using the **masquerade** binding method.

- The VMI you want to access must be running.
- Install the OpenShift CLI (**oc**).

**Procedure**

1. Run the following command to create the **fedora-vm-ssh** service:
   
   ```
   $ virtctl expose vm <fedora-vm> --port=22 --name=fedora-vm-ssh --type=NodePort
   ```

   - `<fedora-vm>` is the name of the VM that you run the **fedora-vm-ssh** service on.

2. Check the service to find out which port the service acquired:
   
   ```
   $ oc get svc
   ```

   **Example output**

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>CLUSTER-IP</th>
<th>EXTERNAL-IP</th>
<th>PORT(S)</th>
<th>AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>fedora-vm-ssh</td>
<td>NodePort</td>
<td>127.0.0.1</td>
<td>&lt;none&gt;</td>
<td>22:32551/TCP</td>
<td>6s</td>
</tr>
</tbody>
</table>

   In this example, the service acquired the **32551** port.

3. Log in to the VMI via SSH. Use the **ipAddress** of any of the cluster nodes and the port that you found in the previous step:

   ```
   $ ssh username@<node_IP_address> -p 32551
   ```

**8.7.3.2. Accessing a virtual machine via SSH with YAML configurations**

You can enable an SSH connection to a virtual machine (VM) without the need to run the **virtctl expose** command. When the YAML file for the VM and the YAML file for the service are configured and applied, the service forwards the SSH traffic to the VM.

The following examples show the configurations for the VM’s YAML file and the service YAML file.

**Prerequisites**

- Install the OpenShift CLI (**oc**).
- Create a namespace for the VM’s YAML file by using the **oc create namespace** command and specifying a name for the namespace.

**Procedure**

1. In the YAML file for the VM, add the label and a value for exposing the service for SSH connections. Enable the **masquerade** feature for the interface:

   ```
   Example VirtualMachine definition
   ```
Name of the namespace created by the `oc create namespace` command.

Label used by the service to identify the virtual machine instances that are enabled for SSH traffic connections. The label can be any `key:value` pair that is added as a `label` to this YAML file and as a `selector` in the service YAML file.

The interface type is `masquerade`.

The name of this interface is `testmasquerade`.

...
2. Create the VM:

   $ oc create -f <path_for_the_VM_YAML_file>

3. Start the VM:

   $ virtctl start vm-ssh

4. In the YAML file for the service, specify the service name, port number, and the target port.

   **Example Service definition**

   ```yaml
   ... 
   apiVersion: v1
   kind: Service
   metadata:
     name: svc-ssh
     namespace: ssh-ns
   spec:
     ports:
       - targetPort: 22
         protocol: TCP
         port: 27017
     selector:
       special: vm-ssh
     type: NodePort
   ...
   ```

   1. Name of the SSH service.
   2. Name of the namespace created by the `oc create namespace` command.
   3. The target port number for the SSH connection.
   4. The selector name and value must match the label specified in the YAML file for the VM.

5. Create the service:

   $ oc create -f <path_for_the_service_YAML_file>

6. Verify that the VM is running:

   $ oc get vmi

   **Example output**

   ```
   NAME    AGE     PHASE       IP              NODENAME
   vm-ssh 6s       Running     10.244.196.152  node01
   ```

7. Check the service to find out which port the service acquired:

   $ oc get svc
Example output

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>CLUSTER-IP</th>
<th>EXTERNAL-IP</th>
<th>PORT(S)</th>
<th>AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>svc-ssh</td>
<td>NodePort</td>
<td>10.106.236.208</td>
<td>&lt;none&gt;</td>
<td>27017:30093/TCP</td>
<td>22s</td>
</tr>
</tbody>
</table>

In this example, the service acquired the port number 30093.

8. Run the following command to obtain the IP address for the node:

```
$ oc get node <node_name> -o wide
```

Example output

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
<th>ROLES</th>
<th>AGE</th>
<th>VERSION</th>
<th>INTERNAL-IP</th>
<th>EXTERNAL-IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>node01</td>
<td>Ready</td>
<td>worker</td>
<td>6d22h</td>
<td>v1.23.0</td>
<td>192.168.55.101</td>
<td>&lt;none&gt;</td>
</tr>
</tbody>
</table>

9. Log in to the VM via SSH by specifying the IP address of the node where the VM is running and the port number. Use the port number displayed by the `oc get svc` command and the IP address of the node displayed by the `oc get node` command. The following example shows the `ssh` command with the username, node’s IP address, and the port number:

```
$ ssh fedora@192.168.55.101 -p 30093
```

8.7.3.3. Accessing the serial console of a virtual machine instance

The `virtctl console` command opens a serial console to the specified virtual machine instance.

Prerequisites

- The `virt-viewer` package must be installed.
- The virtual machine instance you want to access must be running.

Procedure

- Connect to the serial console with `virtctl`:

```
$ virtctl console <VMI>
```

8.7.3.4. Accessing the graphical console of a virtual machine instances with VNC

The `virtctl` client utility can use the `remote-viewer` function to open a graphical console to a running virtual machine instance. This capability is included in the `virt-viewer` package.

Prerequisites

- The `virt-viewer` package must be installed.
- The virtual machine instance you want to access must be running.
NOTE

If you use virtctl via SSH on a remote machine, you must forward the X session to your machine.

Procedure

1. Connect to the graphical interface with the virtctl utility:
   
   $ virtctl vnc <VMI>

2. If the command failed, try using the -v flag to collect troubleshooting information:
   
   $ virtctl vnc <VMI> -v 4

8.7.3.5. Connecting to a Windows virtual machine with an RDP console

The Remote Desktop Protocol (RDP) provides a better console experience for connecting to Windows virtual machines.

To connect to a Windows virtual machine with RDP, specify the IP address of the attached L2 NIC to your RDP client.

Prerequisites

- A running Windows virtual machine with the QEMU guest agent installed. The qemu-guest-agent is included in the VirtIO drivers.
- A layer 2 NIC attached to the virtual machine.
- An RDP client installed on a machine on the same network as the Windows virtual machine.

Procedure

1. Log in to the OpenShift Virtualization cluster through the oc CLI tool as a user with an access token.
   
   $ oc login -u <user> https://<cluster.example.com>:8443

2. Use oc describe vmi to display the configuration of the running Windows virtual machine.
   
   $ oc describe vmi <windows-vmi-name>

Example output

```yaml
...  
spec:  
  networks:  
  - name: default  
    pod: {}  
  - multus:  
    networkName: cnv-bridge  
    name: bridge-net
```
Identify and copy the IP address of the layer 2 network interface. This is 192.0.2.0 in the above example, or 2001:db8:: if you prefer IPv6.

Open an RDP client and use the IP address copied in the previous step for the connection.

Enter the Administrator user name and password to connect to the Windows virtual machine.

### 8.8. AUTOMATING WINDOWS INSTALLATION WITH SYSPREP

You can use Microsoft DVD images and **sysprep** to automate the installation, setup, and software provisioning of Windows virtual machines.

#### 8.8.1. Using a Windows DVD to create a VM disk image

Microsoft does not provide disk images for download, but you can create a disk image using a Windows DVD. This disk image can then be used to create virtual machines.

**Procedure**

1. In the OpenShift Virtualization web console, click **Storage → PersistentVolumeClaims → Create PersistentVolumeClaim With Data upload form**

2. Select the intended project.

3. Set the **Persistent Volume Claim Name**

4. Upload the VM disk image from the Windows DVD. The image is now available as a boot source to create a new Windows VM.

#### 8.8.2. Using a disk image to install Windows

After creating a disk image using a Windows DVD, you can then use that disk image to install Windows on your VM.

**Procedure**
1. Use the OpenShift Virtualization web console VM wizard to create a new Windows VM, using the template available for your version of Windows.

2. Select the DVD image as the boot source.

3. Uncheck **Clone available operating system source to this Virtual Machine**

4. Clear the **Start this virtual machine after creation** checkbox.

5. Click **Customize virtual machine → Advanced**.

6. Under **Sysprep**, specify the **autounattend.xml** answer file settings by following Microsoft guidelines.

7. In the YAML, replace `running:false` with `runStrategy: RerunOnFailure`, and save. The VM will start automatically. The **sysprep** disk containing the **autounattend.xml** answer file is now attached to the VM.

### 8.8.3. Generalizing a Windows VM using sysprep

Generalizing an image allows that image to remove all system-specific configuration data when the image is deployed on a virtual machine.

Before generalizing the VM, you must ensure the **sysprep** tool cannot detect an answer file after the unattended Windows installation.

**Procedure**

1. Remove the **sysprep** disk.
   a. In the web console, select **Virtualization → Virtual Machines**, and select the relevant VM.
   b. Click **Disks**.
   c. Click the **Options menu** for the **sysprep** disk, then click **Delete**.
   d. Click **Detach** in the **Detach sysprep disk** dialog.

2. Rename `C:\Windows\Panther\unattend.xml` to avoid detection by the **sysprep** tool.

3. Start the **sysprep** program by running the following command:

   ```
   \%WINDIR\%\System32\Sysprep\sysprep.exe /generalize /shutdown /oobe /mode:vm
   ```

4. After the **sysprep** tool completes, the Windows VM shuts down. The disk image of the VM is now available to use as an installation image for Windows VMs.

You can now specialize the VM.

### 8.8.4. Specializing a Windows VM

Specializing a virtual machine configures the computer-specific information from the image onto the VM.
IMPORTANT
You must generalize the root disk before specializing the virtual machine.

Procedure

1. Use the OpenShift Virtualization web console VM wizard to create a new Windows VM.
2. When selecting the Boot Source, choose Clone existing PVC, and clone the PVC from the initial VM root disk.
3. Click Customize virtual machine → Advanced
4. Under Sysprep, specify the unattend.xml answer file settings following Microsoft guidelines.
5. Add filler information to the autounattend.xml answer file settings.
6. Start the VM. On first boot, Windows will use the unattend.xml answer file to specialize the VM. The VM is now ready to use.

8.8.5. Additional resources
- Creating virtual machines
- Microsoft, Sysprep (Generalize) a Windows installation
- Microsoft, generalize
- Microsoft, specialize

8.9. TRIGGERING VIRTUAL MACHINE FAILOVER BY RESOLVING A FAILED NODE

If a node fails and machine health checks are not deployed on your cluster, virtual machines (VMs) with RunStrategy: Always configured are not automatically relocated to healthy nodes. To trigger VM failover, you must manually delete the Node object.

NOTE
If you installed your cluster by using installer-provisioned infrastructure and you properly configured machine health checks:

- Failed nodes are automatically recycled.
- Virtual machines with RunStrategy set to Always or RerunOnFailure are automatically scheduled on healthy nodes.

8.9.1. Prerequisites
- A node where a virtual machine was running has the NotReady condition.
- The virtual machine that was running on the failed node has RunStrategy set to Always.
- You have installed the OpenShift CLI (oc).
8.9.2. Deleting nodes from a bare metal cluster

When you delete a node using the CLI, the node object is deleted in Kubernetes, but the pods that exist on the node are not deleted. Any bare pods not backed by a replication controller become inaccessible to OpenShift Container Platform. Pods backed by replication controllers are rescheduled to other available nodes. You must delete local manifest pods.

Procedure

Delete a node from an OpenShift Container Platform cluster running on bare metal by completing the following steps:

1. Mark the node as unschedulable:
   
   ```
   $ oc adm cordon <node_name>
   ```

2. Drain all pods on the node:

   ```
   $ oc adm drain <node_name> --force=true
   ```

   This step might fail if the node is offline or unresponsive. Even if the node does not respond, it might still be running a workload that writes to shared storage. To avoid data corruption, power down the physical hardware before you proceed.

3. Delete the node from the cluster:

   ```
   $ oc delete node <node_name>
   ```

   Although the node object is now deleted from the cluster, it can still rejoin the cluster after reboot or if the kubelet service is restarted. To permanently delete the node and all its data, you must decommission the node.

4. If you powered down the physical hardware, turn it back on so that the node can rejoin the cluster.

8.9.3. Verifying virtual machine failover

After all resources are terminated on the unhealthy node, a new virtual machine instance (VMI) is automatically created on a healthy node for each relocated VM. To confirm that the VMI was created, view all VMIs by using the `oc` CLI.

8.9.3.1. Listing all virtual machine instances using the CLI

You can list all virtual machine instances (VMIs) in your cluster, including standalone VMIs and those owned by virtual machines, by using the `oc` command-line interface (CLI).

Procedure

- List all VMIs by running the following command:

  ```
  $ oc get vmis
  ```

8.10. INSTALLING THE QEMU GUEST AGENT ON VIRTUAL MACHINES
The **QEMU guest agent** is a daemon that runs on the virtual machine and passes information to the host about the virtual machine, users, file systems, and secondary networks.

### 8.10.1. Installing QEMU guest agent on a Linux virtual machine

The **qemu-guest-agent** is widely available and available by default in Red Hat virtual machines. Install the agent and start the service.

To check if your virtual machine (VM) has the QEMU guest agent installed and running, verify that **AgentConnected** is listed in the VM spec.

**NOTE**

To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM’s file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

**Procedure**

1. Access the virtual machine command line through one of the consoles or by SSH.

2. Install the QEMU guest agent on the virtual machine:

   ```bash
   $ yum install -y qemu-guest-agent
   ```

3. Ensure the service is persistent and start it:

   ```bash
   $ systemctl enable --now qemu-guest-agent
   ```

You can also install and start the QEMU guest agent by using the **custom script** field in the **cloud-init** section of the wizard when creating either virtual machines or virtual machines templates in the web console.

### 8.10.2. Installing QEMU guest agent on a Windows virtual machine

For Windows virtual machines, the QEMU guest agent is included in the VirtIO drivers. Install the drivers on an existing or new Windows system.

To check if your virtual machine (VM) has the QEMU guest agent installed and running, verify that **AgentConnected** is listed in the VM spec.
NOTE
To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM’s file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

8.10.2.1. Installing VirtIO drivers on an existing Windows virtual machine
Install the VirtIO drivers from the attached SATA CD drive to an existing Windows virtual machine.

NOTE
This procedure uses a generic approach to adding drivers to Windows. The process might differ slightly between versions of Windows. See the installation documentation for your version of Windows for specific installation steps.

Procedure
1. Start the virtual machine and connect to a graphical console.
2. Log in to a Windows user session.
3. Open Device Manager and expand Other devices to list any Unknown device.
   a. Open the Device Properties to identify the unknown device. Right-click the device and select Properties.
   b. Click the Details tab and select Hardware Ids in the Property list.
   c. Compare the Value for the Hardware Ids with the supported VirtIO drivers.
4. Right-click the device and select Update Driver Software.
5. Click Browse my computer for driver software and browse to the attached SATA CD drive, where the VirtIO drivers are located. The drivers are arranged hierarchically according to their driver type, operating system, and CPU architecture.
6. Click Next to install the driver.
7. Repeat this process for all the necessary VirtIO drivers.
8. After the driver installs, click Close to close the window.
9. Reboot the virtual machine to complete the driver installation.

8.10.2.2. Installing VirtIO drivers during Windows installation
Install the VirtIO drivers from the attached SATA CD driver during Windows installation.
Procedure

1. Start the virtual machine and connect to a graphical console.
2. Begin the Windows installation process.
3. Select the Advanced installation.
4. The storage destination will not be recognized until the driver is loaded. Click Load driver.
5. The drivers are attached as a SATA CD drive. Click OK and browse the CD drive for the storage driver to load. The drivers are arranged hierarchically according to their driver type, operating system, and CPU architecture.
6. Repeat the previous two steps for all required drivers.
7. Complete the Windows installation.

8.11. VIEWING THE QEMU GUEST AGENT INFORMATION FOR VIRTUAL MACHINES

When the QEMU guest agent runs on the virtual machine, you can use the web console to view information about the virtual machine, users, file systems, and secondary networks.

8.11.1. Prerequisites

- Install the QEMU guest agent on the virtual machine.

8.11.2. About the QEMU guest agent information in the web console

When the QEMU guest agent is installed, the Details pane within the Virtual Machine Overview tab and the Details tab display information about the hostname, operating system, time zone, and logged in users.

The Virtual Machine Overview shows information about the guest operating system installed on the virtual machine. The Details tab displays a table with information for logged in users. The Disks tab displays a table with information for file systems.

NOTE

If the QEMU guest agent is not installed, the Virtual Machine Overview tab and the Details tab display information about the operating system that was specified when the virtual machine was created.

8.11.3. Viewing the QEMU guest agent information in the web console

You can use the web console to view information for virtual machines that is passed by the QEMU guest agent to the host.
Procedure

1. Click Workloads → Virtual Machines from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine name to open the Virtual Machine Overview screen and view the Details pane.
4. Click Logged in users to view the Details tab that shows information for users.
5. Click the Disks tab to view information about the file systems.

8.12. MANAGING CONFIG MAPS, SECRETS, AND SERVICE ACCOUNTS IN VIRTUAL MACHINES

You can use secrets, config maps, and service accounts to pass configuration data to virtual machines. For example, you can:

- Give a virtual machine access to a service that requires credentials by adding a secret to the virtual machine.
- Store non-confidential configuration data in a config map so that a pod or another object can consume the data.
- Allow a component to access the API server by associating a service account with that component.

NOTE

OpenShift Virtualization exposes secrets, config maps, and service accounts as virtual machine disks so that you can use them across platforms without additional overhead.

8.12.1. Adding a secret, config map, or service account to a virtual machine

Add a secret, config map, or service account to a virtual machine by using the OpenShift Container Platform web console.

Prerequisites

- The secret, config map, or service account that you want to add must exist in the same namespace as the target virtual machine.

Procedure

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine to open the Virtual Machine Overview screen.
4. Click the Environment tab.
5. Click Select a resource and select a secret, config map, or service account from the list. A six character serial number is automatically generated for the selected resource.
6. Click **Save**.

7. Optional. Add another object by clicking **Add Config Map, Secret or Service Account**

**NOTE**

a. You can reset the form to the last saved state by clicking **Reload**.

b. The **Environment** resources are added to the virtual machine as disks. You can mount the secret, config map, or service account as you would mount any other disk.

c. If the virtual machine is running, changes will not take effect until you restart the virtual machine. The newly added resources are marked as pending changes for both the **Environment** and **Disks** tab in the **Pending Changes** banner at the top of the page.

**Verification**

1. From the **Virtual Machine Overview** page, click the **Disks** tab.

2. Check to ensure that the secret, config map, or service account is included in the list of disks.

3. Optional. Choose the appropriate method to apply your changes:
   
   a. If the virtual machine is running, restart the virtual machine by clicking **Actions → Restart Virtual Machine**.

   b. If the virtual machine is stopped, start the virtual machine by clicking **Actions → Start Virtual Machine**.

You can now mount the secret, config map, or service account as you would mount any other disk.

### 8.12.2. Removing a secret, config map, or service account from a virtual machine

Remove a secret, config map, or service account from a virtual machine by using the OpenShift Container Platform web console.

**Prerequisites**

- You must have at least one secret, config map, or service account that is attached to a virtual machine.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** screen.

4. Click the **Environment** tab.

5. Find the item that you want to delete in the list, and click **Remove** on the right side of the item.
6. Click **Save**.

**NOTE**

You can reset the form to the last saved state by clicking **Reload**.

**Verification**

1. From the **Virtual Machine Overview** page, click the **Disks** tab.

2. Check to ensure that the secret, config map, or service account that you removed is no longer included in the list of disks.

**8.12.3. Additional resources**

- Providing sensitive data to pods
- Understanding and creating service accounts
- Understanding config maps

**8.13. INSTALLING VIRTIO DRIVER ON AN EXISTING WINDOWS VIRTUAL MACHINE**

**8.13.1. About VirtIO drivers**

VirtIO drivers are paravirtualized device drivers required for Microsoft Windows virtual machines to run in OpenShift Virtualization. The supported drivers are available in the **container-nativeirtualization/virtio-win** container disk of the Red Hat Ecosystem Catalog.

The **container-nativeirtualization/virtio-win** container disk must be attached to the virtual machine as a SATA CD drive to enable driver installation. You can install VirtIO drivers during Windows installation on the virtual machine or added to an existing Windows installation.

After the drivers are installed, the **container-nativeirtualization/virtio-win** container disk can be removed from the virtual machine.

See also: [Installing Virtio drivers on a new Windows virtual machine](#).

**8.13.2. Supported VirtIO drivers for Microsoft Windows virtual machines**

**Table 8.3. Supported drivers**

<table>
<thead>
<tr>
<th>Driver name</th>
<th>Hardware ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>viostor</td>
<td>VEN_1AF4&amp;DEV_1001</td>
<td>The block driver. Sometimes displays as an <strong>SCSI Controller</strong> in the <strong>Other devices</strong> group.</td>
</tr>
<tr>
<td></td>
<td>VEN_1AF4&amp;DEV_1042</td>
<td></td>
</tr>
<tr>
<td>Driver name</td>
<td>Hardware ID</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>viorcng</td>
<td>VEN_1AF4&amp;DEV_1005, VEN_1AF4&amp;DEV_1044</td>
<td>The entropy source driver. Sometimes displays as a PCI Device in the Other devices group.</td>
</tr>
<tr>
<td>NetKVM</td>
<td>VEN_1AF4&amp;DEV_1000, VEN_1AF4&amp;DEV_1041</td>
<td>The network driver. Sometimes displays as an Ethernet Controller in the Other devices group. Available only if a VirtIO NIC is configured.</td>
</tr>
</tbody>
</table>

### 8.13.3. Adding VirtIO drivers container disk to a virtual machine

OpenShift Virtualization distributes VirtIO drivers for Microsoft Windows as a container disk, which is available from the Red Hat Ecosystem Catalog. To install these drivers to a Windows virtual machine, attach the `container-nativeirtualization/virtio-win` container disk to the virtual machine as a SATA CD drive in the virtual machine configuration file.

#### Prerequisites

- Download the `container-nativeirtualization/virtio-win` container disk from the Red Hat Ecosystem Catalog. This is not mandatory, because the container disk will be downloaded from the Red Hat registry if it not already present in the cluster, but it can reduce installation time.

#### Procedure

1. Add the `container-nativeirtualization/virtio-win` container disk as a `cdrom` disk in the Windows virtual machine configuration file. The container disk will be downloaded from the registry if it is not already present in the cluster.

```yaml
spec:
domain:
devices:
disks:
  - name: virtiocontainerdisk
    bootOrder: 2
  cdrom:
    bus: sata
volumes:
  - containerDisk:
      image: container-nativeirtualization/virtio-win
      name: virtiocontainerdisk
```

1. OpenShift Virtualization boots virtual machine disks in the order defined in the `VirtualMachine` configuration file. You can either define other disks for the virtual machine before the `container-nativeirtualization/virtio-win` container disk or use the optional `bootOrder` parameter to ensure the virtual machine boots from the correct disk. If you specify the `bootOrder` for a disk, it must be specified for all disks in the configuration.

2. The disk is available once the virtual machine has started:
If you add the container disk to a running virtual machine, use `oc apply -f <vm.yaml>` in the CLI or reboot the virtual machine for the changes to take effect.

If the virtual machine is not running, use `virtctl start <vm>`.

After the virtual machine has started, the VirtIO drivers can be installed from the attached SATA CD drive.

### 8.13.4. Installing VirtIO drivers on an existing Windows virtual machine

Install the VirtIO drivers from the attached SATA CD drive to an existing Windows virtual machine.

**NOTE**

This procedure uses a generic approach to adding drivers to Windows. The process might differ slightly between versions of Windows. See the installation documentation for your version of Windows for specific installation steps.

**Procedure**

1. Start the virtual machine and connect to a graphical console.
2. Log in to a Windows user session.
3. Open **Device Manager** and expand **Other devices** to list any **Unknown device**.
   a. Open the **Device Properties** to identify the unknown device. Right-click the device and select **Properties**.
   b. Click the **Details** tab and select **HardwareIds** in the **Property** list.
   c. Compare the **Value** for the **HardwareIds** with the supported VirtIO drivers.
4. Right-click the device and select **Update Driver Software**.
5. Click **Browse my computer for driver software** and browse to the attached SATA CD drive, where the VirtIO drivers are located. The drivers are arranged hierarchically according to their driver type, operating system, and CPU architecture.
6. Click **Next** to install the driver.
7. Repeat this process for all the necessary VirtIO drivers.
8. After the driver installs, click **Close** to close the window.
9. Reboot the virtual machine to complete the driver installation.

### 8.13.5. Removing the VirtIO container disk from a virtual machine

After installing all required VirtIO drivers to the virtual machine, the **container-native-virtualization/virtio-win** container disk no longer needs to be attached to the virtual machine. Remove the **container-native-virtualization/virtio-win** container disk from the virtual machine configuration file.

**Procedure**

1. Edit the configuration file and remove the **disk** and the **volume**.
$ oc edit vm <vm-name>

spec:
domain:
devices:
disks:
  - name: virtiocontainerdisk
    bootOrder: 2
cdrom:
  bus: sata
volumes:
  - containerDisk:
    image: container-nativeirtualization/virtio-win
    name: virtiocontainerdisk

2. Reboot the virtual machine for the changes to take effect.

8.14. INSTALLING VIRTIO DRIVER ON A NEW WINDOWS VIRTUAL MACHINE

8.14.1. Prerequisites

- Windows installation media accessible by the virtual machine, such as importing an ISO into a data volume and attaching it to the virtual machine.

8.14.2. About VirtIO drivers

VirtIO drivers are paravirtualized device drivers required for Microsoft Windows virtual machines to run in OpenShift Virtualization. The supported drivers are available in the container-native-virtualization/virtio-win container disk of the Red Hat Ecosystem Catalog.

The container-native-virtualization/virtio-win container disk must be attached to the virtual machine as a SATA CD drive to enable driver installation. You can install VirtIO drivers during Windows installation on the virtual machine or added to an existing Windows installation.

After the drivers are installed, the container-native-virtualization/virtio-win container disk can be removed from the virtual machine.

See also: Installing VirtIO driver on an existing Windows virtual machine.

8.14.3. Supported VirtIO drivers for Microsoft Windows virtual machines

Table 8.4. Supported drivers

<table>
<thead>
<tr>
<th>Driver name</th>
<th>Hardware ID</th>
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</tr>
<tr>
<td></td>
<td>VEN_1AF4&amp;DEV_1042</td>
<td></td>
</tr>
</tbody>
</table>
### 8.14.4. Adding VirtIO drivers container disk to a virtual machine

OpenShift Virtualization distributes VirtIO drivers for Microsoft Windows as a container disk, which is available from the Red Hat Ecosystem Catalog. To install these drivers to a Windows virtual machine, attach the `container-native-virtualization/virtio-win` container disk to the virtual machine as a SATA CD drive in the virtual machine configuration file.

#### Prerequisites

- Download the `container-native-virtualization/virtio-win` container disk from the Red Hat Ecosystem Catalog. This is not mandatory, because the container disk will be downloaded from the Red Hat registry if it not already present in the cluster, but it can reduce installation time.

#### Procedure

1. Add the `container-native-virtualization/virtio-win` container disk as a `cdrom` disk in the Windows virtual machine configuration file. The container disk will be downloaded from the registry if it is not already present in the cluster.

```yaml
spec:
  domain:
    devices:
      disks:
        - name: virtiocontainerdisk
          bootOrder: 2
        cdrom:
          bus: sata
      volumes:
        - containerDisk:
            image: container-native-virtualization/virtio-win
            name: virtiocontainerdisk
```

OpenShift Virtualization boots virtual machine disks in the order defined in the `VirtualMachine` configuration file. You can either define other disks for the virtual machine before the `container-native-virtualization/virtio-win` container disk or use the optional `bootOrder` parameter to ensure the virtual machine boots from the correct disk. If you specify the `bootOrder` for a disk, it must be specified for all disks in the configuration.
2. The disk is available once the virtual machine has started:

- If you add the container disk to a running virtual machine, use `oc apply -f <vm.yaml>` in the CLI or reboot the virtual machine for the changes to take effect.

- If the virtual machine is not running, use `virtctl start <vm>`.

After the virtual machine has started, the VirtIO drivers can be installed from the attached SATA CD drive.

### 8.14.5. Installing VirtIO drivers during Windows installation

Install the VirtIO drivers from the attached SATA CD driver during Windows installation.

**NOTE**

This procedure uses a generic approach to the Windows installation and the installation method might differ between versions of Windows. See the documentation for the version of Windows that you are installing.

**Procedure**

1. Start the virtual machine and connect to a graphical console.

2. Begin the Windows installation process.

3. Select the **Advanced** installation.

4. The storage destination will not be recognized until the driver is loaded. Click **Load driver**.

5. The drivers are attached as a SATA CD drive. Click **OK** and browse the CD drive for the storage driver to load. The drivers are arranged hierarchically according to their driver type, operating system, and CPU architecture.

6. Repeat the previous two steps for all required drivers.

7. Complete the Windows installation.

### 8.14.6. Removing the VirtIO container disk from a virtual machine

After installing all required VirtIO drivers to the virtual machine, the *container-native-virtualization/virtio-win* container disk no longer needs to be attached to the virtual machine. Remove the *container-native-virtualization/virtio-win* container disk from the virtual machine configuration file.

**Procedure**

1. Edit the configuration file and remove the **disk** and the **volume**.

   ```
   $ oc edit vm <vm-name>
   
   spec:
   domain:
   devices:
   disks:
   - name: virtiocontainerdisk
   ```
2. Reboot the virtual machine for the changes to take effect.

8.15. ADVANCED VIRTUAL MACHINE MANAGEMENT

8.15.1. Specifying nodes for virtual machines

You can place virtual machines (VMs) on specific nodes by using node placement rules.

8.15.1.1. About node placement for virtual machines

To ensure that virtual machines (VMs) run on appropriate nodes, you can configure node placement rules. You might want to do this if:

- You have several VMs. To ensure fault tolerance, you want them to run on different nodes.
- You have two chatty VMs. To avoid redundant inter-node routing, you want the VMs to run on the same node.
- Your VMs require specific hardware features that are not present on all available nodes.
- You have a pod that adds capabilities to a node, and you want to place a VM on that node so that it can use those capabilities.

NOTE

Virtual machine placement relies on any existing node placement rules for workloads. If workloads are excluded from specific nodes on the component level, virtual machines cannot be placed on those nodes.

You can use the following rule types in the `spec` field of a `VirtualMachine` manifest:

**nodeSelector**

Allows virtual machines to be scheduled on nodes that are labeled with the key-value pair or pairs that you specify in this field. The node must have labels that exactly match all listed pairs.

**affinity**

Enables you to use more expressive syntax to set rules that match nodes with virtual machines. For example, you can specify that a rule is a preference, rather than a hard requirement, so that virtual machines are still scheduled if the rule is not satisfied. Pod affinity, pod anti-affinity, and node affinity are supported for virtual machine placement. Pod affinity works for virtual machines because the `VirtualMachine` workload type is based on the `Pod` object.

NOTE

Affinity rules only apply during scheduling. OpenShift Container Platform does not reschedule running workloads if the constraints are no longer met.
tolerations

Allows virtual machines to be scheduled on nodes that have matching taints. If a taint is applied to a node, that node only accepts virtual machines that tolerate the taint.

8.15.1.2. Node placement examples

The following example YAML file snippets use `nodePlacement`, `affinity`, and `tolerations` fields to customize node placement for virtual machines.

8.15.1.2.1. Example: VM node placement with `nodeSelector`

In this example, the virtual machine requires a node that has metadata containing both `example-key-1 = example-value-1` and `example-key-2 = example-value-2` labels.

```
WARNING
If there are no nodes that fit this description, the virtual machine is not scheduled.
```

Example VM manifest

```
metadata:
  name: example-vm-node-selector
apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
template:
spec:
  nodeSelector:
    example-key-1: example-value-1
    example-key-2: example-value-2
...
```

8.15.1.2.2. Example: VM node placement with pod affinity and pod anti-affinity

In this example, the VM must be scheduled on a node that has a running pod with the label `example-key-1 = example-value-1`. If there is no such pod running on any node, the VM is not scheduled.

If possible, the VM is not scheduled on a node that has any pod with the label `example-key-2 = example-value-2`. However, if all candidate nodes have a pod with this label, the scheduler ignores this constraint.

Example VM manifest

```
metadata:
  name: example-vm-pod-affinity
apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
  affinity:
```
If you use the `requiredDuringSchedulingIgnoredDuringExecution` rule type, the VM is not scheduled if the constraint is not met.

If you use the `preferredDuringSchedulingIgnoredDuringExecution` rule type, the VM is still scheduled if the constraint is not met, as long as all required constraints are met.

8.15.1.2.3. Example: VM node placement with node affinity

In this example, the VM must be scheduled on a node that has the label `example.io/example-key = example-value-1` or the label `example.io/example-key = example-value-2`. The constraint is met if only one of the labels is present on the node. If neither label is present, the VM is not scheduled.

If possible, the scheduler avoids nodes that have the label `example-node-label-key = example-node-label-value`. However, if all candidate nodes have this label, the scheduler ignores this constraint.

Example VM manifest

```yaml
metadata:
  name: example-vm-node-affinity
apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
  affinity:
    nodeAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
        nodeSelectorTerms:
          - matchExpressions:
              - key: example.io/example-key
                operator: In
                values:
                - example-value-1
                - example-value-2
        topologyKey: kubernetes.io/hostname
```
If you use the `requiredDuringSchedulingIgnoredDuringExecution` rule type, the VM is not scheduled if the constraint is not met.

If you use the `preferredDuringSchedulingIgnoredDuringExecution` rule type, the VM is still scheduled if the constraint is not met, as long as all required constraints are met.

8.15.1.2.4. Example: VM node placement with tolerations

In this example, nodes that are reserved for virtual machines are already labeled with the `key=virtualization:NoSchedule` taint. Because this virtual machine has matching tolerations, it can schedule onto the tainted nodes.

**NOTE**

A virtual machine that tolerates a taint is not required to schedule onto a node with that taint.

Example VM manifest

```yaml
metadata:
  name: example-vm-tolerations
apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
tolerations:
- key: "key"
  operator: "Equal"
  value: "virtualization"
  effect: "NoSchedule"
...```

8.15.1.3. Additional resources

- Specifying nodes for virtualization components
- Placing pods on specific nodes using node selectors
- Controlling pod placement on nodes using node affinity rules
- Controlling pod placement using node taints

8.15.2. Configuring certificate rotation
Configure certificate rotation parameters to replace existing certificates.

### 8.15.2.1. Configuring certificate rotation

You can do this during OpenShift Virtualization installation in the web console or after installation in the HyperConverged custom resource (CR).

**Procedure**

1. Open the HyperConverged CR by running the following command:

   ```bash
   $ oc edit hco -n openshift-cnv kubevirt-hyperconverged
   ```

2. Edit the spec.certConfig fields as shown in the following example. To avoid overloading the system, ensure that all values are greater than or equal to 10 minutes. Express all values as strings that comply with the golang `ParseDuration` format.

   ```yaml
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
     namespace: openshift-cnv
   spec:
     certConfig:
       ca:
         duration: 48h0m0s
         renewBefore: 24h0m0s
       server:
         duration: 24h0m0s
         renewBefore: 12h0m0s
   
   1. The value of `ca.renewBefore` must be less than or equal to the value of `ca.duration`.
   2. The value of `server.duration` must be less than or equal to the value of `ca.duration`.
   3. The value of `server.renewBefore` must be less than or equal to the value of `server.duration`.

3. Apply the YAML file to your cluster.

### 8.15.2.2. Troubleshooting certificate rotation parameters

Deleting one or more certConfig values causes them to revert to the default values, unless the default values conflict with one of the following conditions:

- The value of `ca.renewBefore` must be less than or equal to the value of `ca.duration`.
- The value of `server.duration` must be less than or equal to the value of `ca.duration`.
- The value of `server.renewBefore` must be less than or equal to the value of `server.duration`.

If the default values conflict with these conditions, you will receive an error.
If you remove the `server.duration` value in the following example, the default value of `2h0m0s` is greater than the value of `ca.duration`, conflicting with the specified conditions.

**Example**

```yaml
certConfig:
  ca:
    duration: 4h0m0s
    renewBefore: 1h0m0s
  server:
    duration: 4h0m0s
    renewBefore: 4h0m0s
```

This results in the following error message:

`error: hyperconvergeds.hco.kubevirt.io "kubevirt-hyperconverged" could not be patched: admission webhook "validate-hco.kubevirt.io" denied the request: spec.certConfig: ca.duration is smaller than server.duration`

The error message only mentions the first conflict. Review all certConfig values before you proceed.

**8.15.3. Automating management tasks**

You can automate OpenShift Virtualization management tasks by using Red Hat Ansible Automation Platform. Learn the basics by using an Ansible Playbook to create a new virtual machine.

**8.15.3.1. About Red Hat Ansible Automation**

Ansible is an automation tool used to configure systems, deploy software, and perform rolling updates. Ansible includes support for OpenShift Virtualization, and Ansible modules enable you to automate cluster management tasks such as template, persistent volume claim, and virtual machine operations.

Ansible provides a way to automate OpenShift Virtualization management, which you can also accomplish by using the `oc` CLI tool or APIs. Ansible is unique because it allows you to integrate KubeVirt modules with other Ansible modules.

**8.15.3.2. Automating virtual machine creation**

You can use the `kubevirt_vm` Ansible Playbook to create virtual machines in your OpenShift Container Platform cluster using Red Hat Ansible Automation Platform.

**Prerequisites**

- Red Hat Ansible Engine version 2.8 or newer

**Procedure**

1. Edit an Ansible Playbook YAML file so that it includes the `kubevirt_vm` task:
NOTE

This snippet only includes the `kubevirt_vm` portion of the playbook.

2. Edit the values to reflect the virtual machine you want to create, including the `namespace`, the number of `cpu_cores`, the `memory`, and the `disks`. For example:

   ```yaml
   kubevirt_vm:
     namespace: default
     name: vm1
     cpu_cores: 1
     memory: 64Mi
     disks:
       - name: containerdisk
         volume:
           containerDisk:
             image: kubevirt/cirros-container-disk-demo:latest
         disk:
           bus: virtio
   ```

3. If you want the virtual machine to boot immediately after creation, add `state: running` to the YAML file. For example:

   ```yaml
   kubevirt_vm:
     namespace: default
     name: vm1
     state: running
     cpu_cores: 1
   ```

   Changing this value to `state: absent` deletes the virtual machine, if it already exists.

4. Run the `ansible-playbook` command, using your playbook’s file name as the only argument:

   ```sh
   $ ansible-playbook create-vm.yaml
   ```

5. Review the output to determine if the play was successful:

   **Example output**

   ```
   (...)  
   TASK [Create my first VM] *****************************************  
   changed: [localhost]  
   PLAY RECAP
   ```
If you did not include `state: running` in your playbook file and you want to boot the VM now, edit the file so that it includes `state: running` and run the playbook again:

```
$ ansible-playbook create-vm.yaml
```

To verify that the virtual machine was created, try to access the VM console.

### 8.15.3.3. Example: Ansible Playbook for creating virtual machines

You can use the `kubevirt_vm` Ansible Playbook to automate virtual machine creation.

The following YAML file is an example of the `kubevirt_vm` playbook. It includes sample values that you must replace with your own information if you run the playbook.

```yaml
---
- name: Ansible Playbook
  hosts: localhost
  connection: local
  tasks:
    - name: Create my first VM
      kubevirt_vm:
        namespace: default
        name: vm1
        cpu_cores: 1
        memory: 64Mi
        disks:
          - name: containerdisk
            volume:
              containerDisk:
                image: kubevirt/cirros-container-disk-demo:latest
                disk:
                  bus: virtio
```

### Additional information

- [Intro to Playbooks](#)
- [Tools for Validating Playbooks](#)

### 8.15.4. Using EFI mode for virtual machines

You can boot a virtual machine (VM) in Extensible Firmware Interface (EFI) mode.

#### 8.15.4.1. About EFI mode for virtual machines

Extensible Firmware Interface (EFI), like legacy BIOS, initializes hardware components and operating system image files when a computer starts. EFI supports more modern features and customization options than BIOS, enabling faster boot times.
It stores all the information about initialization and startup in a file with a `.efi` extension, which is stored on a special partition called EFI System Partition (ESP). The ESP also contains the boot loader programs for the operating system that is installed on the computer.

### 8.15.4.2. Booting virtual machines in EFI mode

You can configure a virtual machine to boot in EFI mode by editing the VM manifest.

**Prerequisites**

- Install the OpenShift CLI (`oc`).

**Procedure**

1. Create a YAML file that defines a VM object. Use the firmware stanza of the example YAML file:

   **Booting in EFI mode with secure boot active**

   ```yaml
   apiversion: kubevirt.io/v1
   kind: VirtualMachine
   metadata:
     labels:
       special: vm-secureboot
   name: vm-secureboot
   spec:
     template:
       metadata:
         labels:
           special: vm-secureboot
       spec:
         domain:
           devices:
             - disk:
               bus: virtio
               name: containerdisk
           features:
             acpi: {}
             smm:
               enabled: true
           firmware:
             bootloader:
               efi:
                 secureBoot: true
   #...
   ```

1. **OpenShift Virtualization requires System Management Mode (SMM)** to be enabled for Secure Boot in EFI mode to occur.

2. **OpenShift Virtualization supports a VM with or without Secure Boot when using EFI mode.** If Secure Boot is enabled, then EFI mode is required. However, EFI mode can be enabled without using Secure Boot.

2. Apply the manifest to your cluster by running the following command:
8.15.5. Configuring PXE booting for virtual machines

PXE booting, or network booting, is available in OpenShift Virtualization. Network booting allows a computer to boot and load an operating system or other program without requiring a locally attached storage device. For example, you can use it to choose your desired OS image from a PXE server when deploying a new host.

8.15.5.1. Prerequisites

- A Linux bridge must be connected.
- The PXE server must be connected to the same VLAN as the bridge.

8.15.5.2. OpenShift Virtualization networking glossary

OpenShift Virtualization provides advanced networking functionality by using custom resources and plug-ins.

The following terms are used throughout OpenShift Virtualization documentation:

**Container Network Interface (CNI)**

- A Cloud Native Computing Foundation project, focused on container network connectivity. OpenShift Virtualization uses CNI plug-ins to build upon the basic Kubernetes networking functionality.

**Multus**

- A "meta" CNI plug-in that allows multiple CNIs to exist so that a pod or virtual machine can use the interfaces it needs.

**Custom resource definition (CRD)**

- A Kubernetes API resource that allows you to define custom resources, or an object defined by using the CRD API resource.

**Network attachment definition (NAD)**

- A CRD introduced by the Multus project that allows you to attach pods, virtual machines, and virtual machine instances to one or more networks.

**Node network configuration policy (NNCP)**

- A description of the requested network configuration on nodes. You update the node network configuration, including adding and removing interfaces, by applying a `NodeNetworkConfigurationPolicy` manifest to the cluster.

**Preboot eXecution Environment (PXE)**

- An interface that enables an administrator to boot a client machine from a server over the network. Network booting allows you to remotely load operating systems and other software onto the client.

8.15.5.3. PXE booting with a specified MAC address

As an administrator, you can boot a client over the network by first creating a `NetworkAttachmentDefinition` object for your PXE network. Then, reference the network attachment definition in your virtual machine instance configuration file before you start the virtual machine instance. You can also specify a MAC address in the virtual machine instance configuration file, if required by the PXE server.

$ oc create -f <file_name>.yaml
Prerequisites

- A Linux bridge must be connected.
- The PXE server must be connected to the same VLAN as the bridge.

Procedure

1. Configure a PXE network on the cluster:
   a. Create the network attachment definition file for PXE network `pxe-net-conf`:

```
apiVersion: "k8s.cni.cncf.io/v1"
kind: NetworkAttachmentDefinition
metadata:
  name: pxe-net-conf
spec:
  config: '{
    "cniVersion": "0.3.1",
    "name": "pxe-net-conf",
    "plugins": [
      {
        "type": "cnv-bridge",
        "bridge": "br1",
        "vlan": 1
      },
      {
        "type": "cnv-tuning"
      }
    ]
  }
}
```

1 Optional: The VLAN tag.

2 The `cnv-tuning` plug-in provides support for custom MAC addresses.

**NOTE**

The virtual machine instance will be attached to the bridge `br1` through an access port with the requested VLAN.

2. Create the network attachment definition by using the file you created in the previous step:

```
$ oc create -f pxe-net-conf.yaml
```

3. Edit the virtual machine instance configuration file to include the details of the interface and network.

   a. Specify the network and MAC address, if required by the PXE server. If the MAC address is not specified, a value is assigned automatically. Ensure that `bootOrder` is set to 1 so that the interface boots first. In this example, the interface is connected to a network called `<pxe-net>`:

```
interfaces:
```
NOTE

Boot order is global for interfaces and disks.

b. Assign a boot device number to the disk to ensure proper booting after operating system provisioning.
   Set the disk **bootOrder** value to 2:

   ```yaml
   devices:
     disks:
       - disk:
           bus: virtio
           name: containerdisk
           bootOrder: 2
   ```

c. Specify that the network is connected to the previously created network attachment definition. In this scenario, `<pxe-net>` is connected to the network attachment definition called `<pxe-net-conf>`:

   ```yaml
   networks:
     - name: default
       pod: {}
     - name: pxe-net
       multus:
         networkName: pxe-net-conf
   ```

4. Create the virtual machine instance:

   ```bash
   $ oc create -f vmi-pxe-boot.yaml
   ```

**Example output**

```bash
virtualmachineinstance.kubevirt.io "vmi-pxe-boot" created
```

1. Wait for the virtual machine instance to run:

   ```bash
   $ oc get vmi vmi-pxe-boot -o yaml | grep -i phase
   phase: Running
   ```

2. View the virtual machine instance using VNC:

   ```bash
   $ virtctl vnc vmi-pxe-boot
   ```

3. Watch the boot screen to verify that the PXE boot is successful.
4. Log in to the virtual machine instance:

   $ virtctl console vmi-pxe-boot

5. Verify the interfaces and MAC address on the virtual machine and that the interface connected
to the bridge has the specified MAC address. In this case, we used **eth1** for the PXE boot,
without an IP address. The other interface, **eth0**, got an IP address from OpenShift Container
Platform.

   $ ip addr

Example output

```
... 3. eth1: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN group default qcol 1000
     link/ether de:00:00:00:00:de brd ff:ff:ff:ff:ff:ff
```

8.15.5.4. Template: Virtual machine configuration file for PXE booting

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  creationTimestamp: null
labels:
  special: vm-pxe-boot
name: vm-pxe-boot
spec:
template:
  metadata:
    labels:
      special: vm-pxe-boot
spec:
domain:
devices:
disks:
- disk:
  bus: virtio
  name: containerdisk
  bootOrder: 2
- disk:
  bus: virtio
  name: cloudinitdisk
interfaces:
- masquerade: {}
  name: default
- bridge: {}
  name: pxe-net
  macAddress: de:00:00:00:de
  bootOrder: 1

machine:
type: ""
resources:
requests:
  memory: 1024M
```
8.15.6. Managing guest memory

If you want to adjust guest memory settings to suit a specific use case, you can do so by editing the guest’s YAML configuration file. OpenShift Virtualization allows you to configure guest memory overcommitment and disable guest memory overhead accounting.

**WARNING**

The following procedures increase the chance that virtual machine processes will be killed due to memory pressure. Proceed only if you understand the risks.

8.15.6.1. Configuring guest memory overcommitment

If your virtual workload requires more memory than available, you can use memory overcommitment to allocate all or most of the host’s memory to your virtual machine instances (VMIs). Enabling memory overcommitment means that you can maximize resources that are normally reserved for the host.

For example, if the host has 32 GB RAM, you can use memory overcommitment to fit 8 virtual machines (VMs) with 4 GB RAM each. This allocation works under the assumption that the virtual machines will not use all of their memory at the same time.

**IMPORTANT**

Memory overcommitment increases the potential for virtual machine processes to be killed due to memory pressure (OOM killed).

The potential for a VM to be OOM killed varies based on your specific configuration, node memory, available swap space, virtual machine memory consumption, the use of kernel same-page merging (KSM), and other factors.

**Procedure**

```yaml
networks:
  - name: default
    pod: {}
  - multus:
      networkName: pxe-net-conf
      name: pxe-net
terminationGracePeriodSeconds: 180
volumes:
  - name: containerdisk
    containerDisk:
      image: kubevirt/fedora-cloud-container-disk-demo
      cloudInitNoCloud:
        userData: |
        #!/bin/bash
        echo "fedora" | passwd fedora --stdin
        name: cloudinitdisk
status: {}
```

OpenShift Container Platform 4.10 Virtualization
1. To explicitly tell the virtual machine instance that it has more memory available than was requested from the cluster, edit the virtual machine configuration file and set `spec.domain.memory.guest` to a higher value than `spec.domain.resources.requests.memory`. This process is called memory overcommitment. In this example, 1024M is requested from the cluster, but the virtual machine instance is told that it has 2048M available. As long as there is enough free memory available on the node, the virtual machine instance will consume up to 2048M.

   ```yaml
   kind: VirtualMachine
   spec:
     template:
       domain:
         resources:
           requests:
             memory: 1024M
           memory:
             guest: 2048M
   
   NOTE
   The same eviction rules as those for pods apply to the virtual machine instance if the node is under memory pressure.

2. Create the virtual machine:

   $ oc create -f <file_name>.yaml

8.15.6.2. Disabling guest memory overhead accounting

A small amount of memory is requested by each virtual machine instance in addition to the amount that you request. This additional memory is used for the infrastructure that wraps each `VirtualMachineInstance` process.

Though it is not usually advisable, it is possible to increase the virtual machine instance density on the node by disabling guest memory overhead accounting.

   IMPORTANT

   Disabling guest memory overhead accounting increases the potential for virtual machine processes to be killed due to memory pressure (OOM killed).

   The potential for a VM to be OOM killed varies based on your specific configuration, node memory, available swap space, virtual machine memory consumption, the use of kernel same-page merging (KSM), and other factors.

   Procedure

   1. To disable guest memory overhead accounting, edit the YAML configuration file and set the `overcommitGuestOverhead` value to `true`. This parameter is disabled by default.

   ```yaml
   kind: VirtualMachine
   spec:
     template:
   ```
If `overcommitGuestOverhead` is enabled, it adds the guest overhead to memory limits, if present.

2. Create the virtual machine:

```
$ oc create -f <file_name>.yaml
```

8.15.7. Using huge pages with virtual machines

You can use huge pages as backing memory for virtual machines in your cluster.

8.15.7.1. Prerequisites

- Nodes must have pre-allocated huge pages configured.

8.15.7.2. What huge pages do

Memory is managed in blocks known as pages. On most systems, a page is 4Ki. 1Mi of memory is equal to 256 pages; 1Gi of memory is 256,000 pages, and so on. CPUs have a built-in memory management unit that manages a list of these pages in hardware. The Translation Lookaside Buffer (TLB) is a small hardware cache of virtual-to-physical page mappings. If the virtual address passed in a hardware instruction can be found in the TLB, the mapping can be determined quickly. If not, a TLB miss occurs, and the system falls back to slower, software-based address translation, resulting in performance issues. Since the size of the TLB is fixed, the only way to reduce the chance of a TLB miss is to increase the page size.

A huge page is a memory page that is larger than 4Ki. On x86_64 architectures, there are two common huge page sizes: 2Mi and 1Gi. Sizes vary on other architectures. To use huge pages, code must be written so that applications are aware of them. Transparent Huge Pages (THP) attempt to automate the management of huge pages without application knowledge, but they have limitations. In particular, they are limited to 2Mi page sizes. THP can lead to performance degradation on nodes with high memory utilization or fragmentation due to defragmenting efforts of THP, which can lock memory pages. For this reason, some applications may be designed to (or recommend) usage of pre-allocated huge pages instead of THP.

In OpenShift Virtualization, virtual machines can be configured to consume pre-allocated huge pages.

8.15.7.3. Configuring huge pages for virtual machines

You can configure virtual machines to use pre-allocated huge pages by including the `memory.hugepages.pageSize` and `resources.requests.memory` parameters in your virtual machine configuration.

The memory request must be divisible by the page size. For example, you cannot request 500Mi memory with a page size of 1Gi.
NOTE

The memory layouts of the host and the guest OS are unrelated. Huge pages requested in the virtual machine manifest apply to QEMU. Huge pages inside the guest can only be configured based on the amount of available memory of the virtual machine instance.

If you edit a running virtual machine, the virtual machine must be rebooted for the changes to take effect.

Prerequisites

- Nodes must have pre-allocated huge pages configured.

Procedure

1. In your virtual machine configuration, add the `resources.requests.memory` and `memory.hugepages.pageSize` parameters to the `spec.domain`. The following configuration snippet is for a virtual machine that requests a total of 4Gi memory with a page size of 1Gi:

   ```yaml
   kind: VirtualMachine
   ...
   spec:
     domain:
       resources:
         requests:
           memory: "4Gi" ¹
           memory:
             hugepages:
               pageSize: "1Gi" ²
   ...
   
   ¹ The total amount of memory requested for the virtual machine. This value must be divisible by the page size.
   ² The size of each huge page. Valid values for x86_64 architecture are 1Gi and 2Mi. The page size must be smaller than the requested memory.

2. Apply the virtual machine configuration:

   ```bash
   $ oc apply -f <virtual_machine>.yaml
   ```

8.15.8. Enabling dedicated resources for virtual machines

To improve performance, you can dedicate node resources, such as CPU, to a virtual machine.

8.15.8.1. About dedicated resources

When you enable dedicated resources for your virtual machine, your virtual machine’s workload is scheduled on CPUs that will not be used by other processes. By using dedicated resources, you can improve the performance of the virtual machine and the accuracy of latency predictions.

8.15.8.2. Prerequisites
The CPU Manager must be configured on the node. Verify that the node has the `cpumanager = true` label before scheduling virtual machine workloads.

- The virtual machine must be powered off.

8.15.8.3. Enabling dedicated resources for a virtual machine

You can enable dedicated resources for a virtual machine in the Details tab. Virtual machines that were created by using a Red Hat template or the wizard can be enabled with dedicated resources.

**Procedure**

1. Click Workloads → Virtual Machines from the side menu.
2. Select a virtual machine to open the Virtual Machine tab.
3. Click the Details tab.
4. Click the pencil icon to the right of the Dedicated Resources field to open the Dedicated Resources window.
5. Select Schedule this workload with dedicated resources (guaranteed policy)
6. Click Save.

8.15.9. Scheduling virtual machines

You can schedule a virtual machine (VM) on a node by ensuring that the VM’s CPU model and policy attribute are matched for compatibility with the CPU models and policy attributes supported by the node.

8.15.9.1. Policy attributes

You can schedule a virtual machine (VM) by specifying a policy attribute and a CPU feature that is matched for compatibility when the VM is scheduled on a node. A policy attribute specified for a VM determines how that VM is scheduled on a node.

<table>
<thead>
<tr>
<th>Policy attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>force</td>
<td>The VM is forced to be scheduled on a node. This is true even if the host CPU does not support the VM’s CPU.</td>
</tr>
<tr>
<td>require</td>
<td>Default policy that applies to a VM if the VM is not configured with a specific CPU model and feature specification. If a node is not configured to support CPU node discovery with this default policy attribute or any one of the other policy attributes, VMs are not scheduled on that node. Either the host CPU must support the VM’s CPU or the hypervisor must be able to emulate the supported CPU model.</td>
</tr>
<tr>
<td>optional</td>
<td>The VM is added to a node if that VM is supported by the host’s physical machine CPU.</td>
</tr>
<tr>
<td>disable</td>
<td>The VM cannot be scheduled with CPU node discovery.</td>
</tr>
</tbody>
</table>
8.15.9.2. Setting a policy attribute and CPU feature

You can set a policy attribute and CPU feature for each virtual machine (VM) to ensure that it is scheduled on a node according to policy and feature. The CPU feature that you set is verified to ensure that it is supported by the host CPU or emulated by the hypervisor.

Procedure

- Edit the `domain` spec of your VM configuration file. The following example sets the CPU feature and the `require` policy for a virtual machine (VM):

  ```yaml
  apiVersion: kubevirt.io/v1
  kind: VirtualMachine
  metadata:
    name: myvm
  spec:
    template:
      spec:
        domain:
          cpu:
            features:
              - name: apic
            policy: require
  ```

  1. Name of the CPU feature for the VM.
  2. Policy attribute for the VM.

8.15.9.3. Scheduling virtual machines with the supported CPU model

You can configure a CPU model for a virtual machine (VM) to schedule it on a node where its CPU model is supported.

Procedure

- Edit the `domain` spec of your virtual machine configuration file. The following example shows a specific CPU model defined for a VM:

  ```yaml
  apiVersion: kubevirt.io/v1
  kind: VirtualMachine
  metadata:
    name: myvm
  spec:
    template:
      spec:
  ```
8.15.9.4. Scheduling virtual machines with the host model

When the CPU model for a virtual machine (VM) is set to **host-model**, the VM inherits the CPU model of the node where it is scheduled.

**Procedure**

- Edit the `domain` spec of your VM configuration file. The following example shows `host-model` being specified for the virtual machine:

```yaml
apiVersion: kubevirt/v1alpha3
kind: VirtualMachine
metadata:
  name: myvm
spec:
template:
  spec:
    domain:
      cpu:
        model: host-model

1 The VM that inherits the CPU model of the node where it is scheduled.

8.15.10. Configuring PCI passthrough

The Peripheral Component Interconnect (PCI) passthrough feature enables you to access and manage hardware devices from a virtual machine. When PCI passthrough is configured, the PCI devices function as if they were physically attached to the guest operating system.

Cluster administrators can expose and manage host devices that are permitted to be used in the cluster by using the `oc` command-line interface (CLI).

8.15.10.1. About preparing a host device for PCI passthrough

To prepare a host device for PCI passthrough by using the CLI, create a `MachineConfig` object and add kernel arguments to enable the Input-Output Memory Management Unit (IOMMU). Bind the PCI device to the Virtual Function I/O (VFIO) driver and then expose it in the cluster by editing the `permittedHostDevices` field of the `HyperConverged` custom resource (CR). The `permittedHostDevices` list is empty when you first install the OpenShift Virtualization Operator.

To remove a PCI host device from the cluster by using the CLI, delete the PCI device information from the `HyperConverged` CR.

8.15.10.1.1. Adding kernel arguments to enable the IOMMU driver
To enable the IOMMU (Input-Output Memory Management Unit) driver in the kernel, create the `MachineConfig` object and add the kernel arguments.

**Prerequisites**

- Administrative privilege to a working OpenShift Container Platform cluster.
- Intel or AMD CPU hardware.
- Intel Virtualization Technology for Directed I/O extensions or AMD IOMMU in the BIOS (Basic Input/Output System) is enabled.

**Procedure**

1. Create a `MachineConfig` object that identifies the kernel argument. The following example shows a kernel argument for an Intel CPU.

```yaml
apiVersion: machineconfiguration.openshift.io/v1
class: MachineConfig
metadata:
  labels:
    machineconfiguration.openshift.io/machine: worker
name: 100-worker-iommu
spec:
  config:
    ignition:
      version: 3.2.0
    kernelArguments:
      - intel_iommu=on

$ oc create -f 100-worker-kernel-arg-iommu.yaml
```

1. Applies the new kernel argument only to worker nodes.
2. The `name` indicates the ranking of this kernel argument (100) among the machine configs and its purpose. If you have an AMD CPU, specify the kernel argument as `amd_iommu=on`.
3. Identifies the kernel argument as `intel_iommu` for an Intel CPU.

2. Create the new `MachineConfig` object:

   ```bash
   $ oc create -f 100-worker-kernel-arg-iommu.yaml
   ```

**Verification**

- Verify that the new `MachineConfig` object was added.

  ```bash
  $ oc get MachineConfig
  ```

8.15.10.1.2. Binding PCI devices to the VFIO driver

To bind PCI devices to the VFIO (Virtual Function I/O) driver, obtain the values for `vendor-ID` and `device-ID` from each device and create a list with the values. Add this list to the `MachineConfig` object. The `MachineConfig` Operator generates the `/etc/modprobe.d/vfio.conf` on the nodes with the PCI
devices, and binds the PCI devices to the VFIO driver.

Prerequisites

- You added kernel arguments to enable IOMMU for the CPU.

Procedure

1. Run the `lspci` command to obtain the **vendor-ID** and the **device-ID** for the PCI device.

```bash
$ lspci -nnv | grep -i nvidia
```

**Example output**

```
02:01.0 3D controller [0302]: NVIDIA Corporation GV100GL [Tesla V100 PCIe 32GB] [10de:1eb8] (rev a1)
```

2. Create a Butane config file, **100-worker-vfiopci.bu**, binding the PCI device to the VFIO driver.

**NOTE**

See "Creating machine configs with Butane" for information about Butane.

**Example**

```yaml
variant: openshift
version: 4.10.0
metadata:
  name: 100-worker-vfiopci
  labels:
    machineconfiguration.openshift.io/role: worker
storage:
  files:
  - path: /etc/modprobe.d/vfio.conf
    mode: 0644
    overwrite: true
    contents:
      inline:
        options vfio-pci ids=10de:1eb8
  - path: /etc/modules-load.d/vfio-pci.conf
    mode: 0644
    overwrite: true
    contents:
      inline: vfio-pci
```

1. Applies the new kernel argument only to worker nodes.
2. Specify the previously determined **vendor-ID** value (**10de**) and the **device-ID** value (**1eb8**) to bind a single device to the VFIO driver. You can add a list of multiple devices with their vendor and device information.
3. The file that loads the vfio-pci kernel module on the worker nodes.
3. Use Butane to generate a `MachineConfig` object file, `100-worker-vfiopci.yaml`, containing the configuration to be delivered to the worker nodes:

   $ butane 100-worker-vfiopci.bu -o 100-worker-vfiopci.yaml

4. Apply the `MachineConfig` object to the worker nodes:

   $ oc apply -f 100-worker-vfiopci.yaml

5. Verify that the `MachineConfig` object was added.

   $ oc get MachineConfig

**Example output**

<table>
<thead>
<tr>
<th>NAME</th>
<th>GENERATEDBYCONTROLLER</th>
<th>IGNITIONVERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>00-master</td>
<td>d3da910bfa9f4b599af4ed7f5ac270d55950a3a1</td>
<td>3.2.0</td>
</tr>
<tr>
<td>00-worker</td>
<td>d3da910bfa9f4b599af4ed7f5ac270d55950a3a1</td>
<td>3.2.0</td>
</tr>
<tr>
<td>01-master-container-runtime</td>
<td>d3da910bfa9f4b599af4ed7f5ac270d55950a3a1</td>
<td>3.2.0</td>
</tr>
<tr>
<td>01-master-kubelet</td>
<td>d3da910bfa9f4b599af4ed7f5ac270d55950a3a1</td>
<td>3.2.0</td>
</tr>
<tr>
<td>01-worker-container-runtime</td>
<td>d3da910bfa9f4b599af4ed7f5ac270d55950a3a1</td>
<td>3.2.0</td>
</tr>
<tr>
<td>01-worker-kubelet</td>
<td>d3da910bfa9f4b599af4ed7f5ac270d55950a3a1</td>
<td>3.2.0</td>
</tr>
<tr>
<td>100-worker-iommu</td>
<td></td>
<td>3.2.0</td>
</tr>
<tr>
<td>100-worker-vfiopci-configuration</td>
<td></td>
<td>3.2.0</td>
</tr>
</tbody>
</table>

**Verification**

- Verify that the VFIO driver is loaded.

  $ lspci -nnk -d 10de:

  The output confirms that the VFIO driver is being used.

**Example output**

```
04:00.0 3D controller [0302]: NVIDIA Corporation GP102GL [Tesla P40] [10de:1eb8] (rev a1)
  Subsystem: NVIDIA Corporation Device [10de:1eb8]
  Kernel driver in use: vfio-pci
  Kernel modules: nouveau
```

8.15.10.1.3. Exposing PCI host devices in the cluster using the CLI

To expose PCI host devices in the cluster, add details about the PCI devices to the `spec.permittedHostDevices.pciHostDevices` array of the `HyperConverged` custom resource (CR).

**Procedure**

1. Edit the `HyperConverged` CR in your default editor by running the following command:
Add the PCI device information to the `spec.permittedHostDevices.pciHostDevices` array. For example:

Example configuration file

```
apiVersion: hco.kubevirt.io/v1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  permittedHostDevices: 1
  pciHostDevices: 2
  - pciDeviceSelector: "10DE:1DB6" 3
    resourceName: "nvidia.com/GV100GL_Tesla_V100" 4
  - pciDeviceSelector: "10DE:1EB8"
    resourceName: "nvidia.com/TU104GL_Tesla_T4"
  - pciDeviceSelector: "8086:6F54"
    resourceName: "intel.com/qat"
  externalResourceProvider: true 5
```

1. The host devices that are permitted to be used in the cluster.
2. The list of PCI devices available on the node.
3. The vendor-ID and the device-ID required to identify the PCI device.
4. The name of a PCI host device.
5. Optional: Setting this field to `true` indicates that the resource is provided by an external device plug-in. OpenShift Virtualization allows the usage of this device in the cluster but leaves the allocation and monitoring to an external device plug-in.

NOTE

The above example snippet shows two PCI host devices that are named `nvidia.com/GV100GL_Tesla_V100` and `nvidia.com/TU104GL_Tesla_T4` added to the list of permitted host devices in the `HyperConverged` CR. These devices have been tested and verified to work with OpenShift Virtualization.

3. Save your changes and exit the editor.

Verification

- Verify that the PCI host devices were added to the node by running the following command. The example output shows that there is one device each associated with the `nvidia.com/GV100GL_Tesla_V100`, `nvidia.com/TU104GL_Tesla_T4`, and `intel.com/qat` resource names.
8.15.10.1.4. Removing PCI host devices from the cluster using the CLI

To remove a PCI host device from the cluster, delete the information for that device from the **HyperConverged** custom resource (CR).

**Procedure**

1. Edit the **HyperConverged** CR in your default editor by running the following command:

   ```bash
   $ oc edit hyperconverged kubevirt-hyperconverged -n openshift-cnv
   ```

2. Remove the PCI device information from the `spec.permittedHostDevices.pciHostDevices` array by deleting the `pciDeviceSelector`, `resourceName` and `externalResourceProvider` (if applicable) fields for the appropriate device. In this example, the `intel.com/qat` resource has been deleted.

**Example configuration file**

```yaml
apiVersion: hco.kubevirt.io/v1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
```
Verification

- Verify that the PCI host device was removed from the node by running the following command. The example output shows that there are zero devices associated with the `intel.com/qat` resource name.

```
$ oc describe node <node_name>
```

Example output

```
Capacity:
  cpu: 64
  devices.kubevirt.io/kvm: 110
  devices.kubevirt.io/tun: 110
  devices.kubevirt.io/vhost-net: 110
  ephemeral-storage: 915128Mi
  hugepages-1Gi: 0
  hugepages-2Mi: 0
  memory: 131395264Ki
  nvidia.com/GV100GL_Tesla_V100 1
  nvidia.com/TU104GL_Tesla_T4 1
  intel.com/qat: 0
  pods: 250
Allocatable:
  cpu: 63500m
  devices.kubevirt.io/kvm: 110
  devices.kubevirt.io/tun: 110
  devices.kubevirt.io/vhost-net: 110
  ephemeral-storage: 863623130526
  hugepages-1Gi: 0
  hugepages-2Mi: 0
  memory: 130244288Ki
  nvidia.com/GV100GL_Tesla_V100 1
  nvidia.com/TU104GL_Tesla_T4 1
  intel.com/qat: 0
  pods: 250
```

8.15.10.2. Configuring virtual machines for PCI passthrough

After the PCI devices have been added to the cluster, you can assign them to virtual machines. The PCI devices are now available as if they are physically connected to the virtual machines.

8.15.10.2.1. Assigning a PCI device to a virtual machine
When a PCI device is available in a cluster, you can assign it to a virtual machine and enable PCI passthrough.

**Procedure**

- Assign the PCI device to a virtual machine as a host device.

**Example**

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
domain:
devices:
hostDevices:
- deviceName: nvidia.com/TU104GL_Tesla_T4
  name: hostdevices1
```

The name of the PCI device that is permitted on the cluster as a host device. The virtual machine can access this host device.

**Verification**

- Use the following command to verify that the host device is available from the virtual machine.

```bash
$ lspci -nnk | grep NVIDIA
```

**Example output**

```bash
$ 02:01.0 3D controller [0302]: NVIDIA Corporation GV100GL [Tesla V100 PCIe 32GB] [10de:1eb8] (rev a1)
```

**8.15.10.3. Additional resources**

- Enabling Intel VT-X and AMD-V Virtualization Hardware Extensions in BIOS
- Managing file permissions
- Post-installation machine configuration tasks

**8.15.11. Configuring vGPU passthrough**

Your virtual machines can access a virtual GPU (vGPU) hardware. Assigning a vGPU to your virtual machine allows you do the following:

- Access a fraction of the underlying hardware’s GPU to achieve high performance benefits in your virtual machine.
- Streamline resource-intensive I/O operations.
IMPORTANT

vGPU passthrough can only be assigned to devices that are connected to clusters running in a bare metal environment.

8.15.11.1. Assigning vGPU passthrough to virtual machines

Use the OpenShift Container Platform web console to assign vGPU devices to your virtual machines.

Prerequisites

- Ensure your cluster and virtual machines are deployed in a bare metal environment. At this time, no other environments are supported.

Procedure

1. Assign a virtual GPU device to your virtual machine:
   a. In the OpenShift Container Platform web console, click Virtualization → Virtual Machines from the side menu.
   b. Select the virtual machine to which you want to assign the device.
   c. Click the Details tab:
      - The Hardware Devices field includes links to add or remove GPU devices and Host devices.
      - Assigning a vGPU using GPU devices enables VNC console access for the attached virtual GPU. Assigning a vGPU using Host Devices does not enable VNC console access.
      - Use the minus icon to remove an existing hardware device.
      - You can only add or remove devices from your virtual machine when it is stopped.
   d. Click the pencil icon and use the pop-up windows to add or remove devices, selecting the appropriate hardware resource names.
   e. Click Save.

2. Click the YAML tab to verify that the new devices have been added to your cluster configuration in the hostDevices section.
NOTE

You can add hardware devices to virtual machines using the OpenShift Container Platform web console when you create a virtual machine or create a virtual machine using a template that you customize. You cannot add devices to pre-supplied boot source templates for specific operating systems, such as Windows 10 or RHEL 7.

To add or remove hardware devices to a custom template that you create, click the Advanced tab in the Create Virtual Machine wizard and click Hardware devices. Use the minus icon to remove an existing hardware device. You can only add or remove devices from your virtual machine when it is stopped.

To display resources that are connected to your cluster, click Compute → Hardware Devices from the side menu.

8.15.11.2. Additional resources

- Creating virtual machines
- Creating virtual machine templates

8.15.12. Configuring mediated devices

OpenShift Virtualization automatically creates mediated devices, such as virtual GPUs (vGPUs), if you provide a list of devices in the HyperConverged custom resource (CR).

IMPORTANT

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

For more information about the support scope of Red Hat Technology Preview features, see https://access.redhat.com/support/offerings/techpreview/.

8.15.12.1. Prerequisites

- If your hardware vendor provides drivers, you installed them on the nodes where you want to create mediated devices.
  - If you use NVIDIA cards, you installed the NVIDIA GRID driver.

8.15.12.2. About using virtual GPUs with OpenShift Virtualization

Some graphics processing unit (GPU) cards support the creation of virtual GPUs (vGPUs). OpenShift Virtualization can automatically create vGPUs and other mediated devices if an administrator provides configuration details in the HyperConverged custom resource (CR). This automation is especially useful for large clusters.

NOTE

Refer to your hardware vendor’s documentation for functionality and support details.
Mediated device
A physical device that is divided into one or more virtual devices. A vGPU is a type of mediated device (mdev); the performance of the physical GPU is divided among the virtual devices. You can assign mediated devices to one or more virtual machines (VMs), but the number of guests must be compatible with your GPU. Some GPUs do not support multiple guests.

8.15.12.2.1. Configuration overview
When configuring mediated devices, an administrator must:

- Create the mediated devices.
- Expose the mediated devices to the cluster.

The *HyperConverged* CR includes APIs that accomplish both tasks:

Creating mediated devices

```yaml
... spec:  mediatedDevicesConfiguration:  mediatedDevicesTypes: <>  - <device_type>  nodeMediatedDeviceTypes: <>  - mediatedDevicesTypes: <>  - <device_type>  nodeSelector: <>  
  <node_selector_key>: <node_selector_value>  ...

<> Required: Configures global settings for the cluster. <> Optional: Overrides the global configuration for a specific node or group of nodes. Must be used with the global *mediatedDevicesTypes* configuration. <> Required if you use *nodeMediatedDeviceTypes*. Overrides the global *mediatedDevicesTypes* configuration for select nodes. <> Required if you use *nodeMediatedDeviceTypes*. Must include a key:value pair.

Exposing mediated devices to the cluster

```yaml
... permittedHostDevices:  mediatedDevices:  - mdevNameSelector: GRID T4-2Q <>  
  resourceName: nvidia.com/GRID_T4-2Q  ...

<> Exposes the mediated devices that map to this value on the host.
```
NOTE

You can see the mediated device types that your device supports by viewing the contents of /sys/bus/pci/devices/<slot>:<bus>:<domain>.

For example, the name file for the nvidia-231 type contains the selector string GRID T4-2Q. Using GRID T4-2Q as the mdevNameSelector value allows nodes to use the nvidia-231 type.

8.15.12.2. How vGPUs are assigned to nodes

For each physical device, OpenShift Virtualization configures:

- A single mdev type.
- The maximum number of instances of the selected mdev type.

The cluster architecture affects how devices are created and assigned to nodes.

Large cluster with multiple cards per node

On nodes with multiple cards that can support similar vGPU types, the relevant device types are created in a round-robin manner. For example:

```yaml
... mediatedDevicesConfiguration:
  mediatedDevicesTypes:
    - nvidia-222
    - nvidia-228
    - nvidia-105
    - nvidia-108
    ... nvidia-105
    ... nvidia-108
    nvidia-217
    nvidia-299
    ...
```

In this scenario, each node has two cards, both of which support the following vGPU types:

- nvidia-105
- nvidia-108
- nvidia-217
- nvidia-299

On each node, OpenShift Virtualization creates:

- 16 vGPUs of type nvidia-105 on the first card.
- 2 vGPUs of type nvidia-108 on the second card.

One node has a single card that supports more than one requested vGPU type

OpenShift Virtualization uses the supported type that comes first on the mediatedDevicesTypes list.

For example, a node’s card supports nvidia-223 and nvidia-224. The following mediatedDevicesTypes list is configured:

```yaml
...
```
In this example, OpenShift Virtualization uses the `nvidia-223` type.

8.15.12.2.3. About changing and removing mediated devices

OpenShift Virtualization updates the cluster’s mediated device configuration if:

- You edit the `HyperConverged` CR and change the contents of the `mediatedDevicesTypes` stanza.
- You change the node labels that match the `nodeMediatedDeviceTypes` node selector.
- You remove the device information from the `spec.mediatedDevicesConfiguration` and `spec.permittedHostDevices` stanzas of the `HyperConverged` CR.

**NOTE**

If you remove the device information from the `spec.permittedHostDevices` stanza without also removing it from the `spec.mediatedDevicesConfiguration` stanza, you cannot create a new mediated device type on the same node. To properly remove mediated devices, remove the device information from both stanzas.

Depending on the specific changes, these actions cause OpenShift Virtualization to reconfigure mediated devices or remove them from the cluster nodes.

8.15.12.3. Preparing hosts for mediated devices

You must enable the IOMMU (Input-Output Memory Management Unit) driver before you can configure mediated devices.

8.15.12.3.1. Adding kernel arguments to enable the IOMMU driver

To enable the IOMMU (Input–Output Memory Management Unit) driver in the kernel, create the `MachineConfig` object and add the kernel arguments.

**Prerequisites**

- Administrative privilege to a working OpenShift Container Platform cluster.
- Intel or AMD CPU hardware.
- Intel Virtualization Technology for Directed I/O extensions or AMD IOMMU in the BIOS (Basic Input/Output System) is enabled.

**Procedure**
1. Create a **MachineConfig** object that identifies the kernel argument. The following example shows a kernel argument for an Intel CPU.

   ```yaml
   apiVersion: machineconfiguration.openshift.io/v1
   kind: MachineConfig
   metadata:
     labels:
       machineconfiguration.openshift.io/role: worker ①
     name: 100-worker-iommu ②
   spec:
     config:
       ignition:
         version: 3.2.0
       kernelArguments:
         - intel_iommu=on ③
   ...
   ``

   ① Applies the new kernel argument only to worker nodes.
   ② The name indicates the ranking of this kernel argument (100) among the machine configs and its purpose. If you have an AMD CPU, specify the kernel argument as `amd_iommu=on`.
   ③ Identifies the kernel argument as `intel_iommu` for an Intel CPU.

2. Create the new **MachineConfig** object:

   ```bash
   $ oc create -f 100-worker-kernel-arg-iommu.yaml
   $ oc get MachineConfig
   $ oc edit hyperconverged kubevirt-hyperconverged -n openshift-cnv
   ``

**Verification**

- Verify that the new **MachineConfig** object was added.

**8.15.12.4. Adding and removing mediated devices**

**8.15.12.4.1. Creating and exposing mediated devices**

You can expose and create mediated devices such as virtual GPUs (vGPUs) by editing the **HyperConverged** custom resource (CR).

**Prerequisites**

- You enabled the IOMMU (Input-Output Memory Management Unit) driver.

**Procedure**

1. Edit the **HyperConverged** CR in your default editor by running the following command:

   ```bash
   $ oc edit hyperconverged kubevirt-hyperconverged -n openshift-cnv
   ```
2. Add the mediated device information to the `HyperConverged` CR `spec`, ensuring that you include the `mediatedDevicesConfiguration` and `permittedHostDevices` stanzas. For example:

```yaml
apiVersion: hco.kubevirt.io/v1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  mediatedDevicesConfiguration:
    mediatedDevicesTypes:
      - nvidia-231
    nodeMediatedDeviceTypes:
      - mediatedDevicesTypes:
          - nvidia-233
    nodeSelector:
      kubernetes.io/hostname: node-11.redhat.com
  permittedHostDevices:
    mediatedDevices:
      - mdevNameSelector: GRID T4-2Q
        resourceName: nvidia.com/GRID_T4-2Q
      - mdevNameSelector: GRID T4-8Q
        resourceName: nvidia.com/GRID_T4-8Q
...
```

<> Creates mediated devices. <> Required: Global `mediatedDevicesTypes` configuration. <> Optional: Overrides the global configuration for specific nodes. <> Required if you use `nodeMediatedDeviceTypes`. <> Exposes mediated devices to the cluster.

3. Save your changes and exit the editor.

**Verification**

- You can verify that a device was added to a specific node by running the following command:

  ```
  $ oc describe node <node_name>
  ```

8.15.12.4.2. Removing mediated devices from the cluster using the CLI

To remove a mediated device from the cluster, delete the information for that device from the `HyperConverged` custom resource (CR).

**Procedure**

1. Edit the `HyperConverged` CR in your default editor by running the following command:

  ```
  $ oc edit hyperconverged kubevirt-hyperconverged -n openshift-cnv
  ```

2. Remove the device information from the `spec.mediatedDevicesConfiguration` and `spec.permittedHostDevices` stanzas of the `HyperConverged` CR. Removing both entries ensures that you can later create a new mediated device type on the same node. For example:
Example configuration file

apiVersion: hco.kubevirt.io/v1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  mediatedDevicesConfiguration:
    mediatedDevicesTypes:
      - nvidia-231
  permittedHostDevices:
    mediatedDevices:
      - mdevNameSelector: GRID T4-2Q
        resourceName: nvidia.com/GRID_T4-2Q

To remove the nvidia-231 device type, delete it from the mediatedDevicesTypes array.

To remove the GRID T4-2Q device, delete the mdevNameSelector field and its corresponding resourceName field.

3. Save your changes and exit the editor.

8.15.12.5. Assigning a mediated device to a virtual machine

Assign mediated devices such as virtual GPUs (vGPUs) to virtual machines.

Prerequisites

- The mediated device is configured in the HyperConverged custom resource.

Procedure

- Assign the mediated device to a virtual machine (VM) by editing the spec.domain.devices.gpus stanza of the VirtualMachine manifest:

Example virtual machine manifest

apiVersion: kubevirt.io/v1
kind: VirtualMachine
spec:
  domain:
    devices:
      gpus:
        - deviceName: nvidia.com/TU104GL_Tesla_T4 ①
          name: gpu1 ②
        - deviceName: nvidia.com/GRID_T4-1Q
          name: gpu2

① The resource name associated with the mediated device.
② A name to identify the device on the VM.
Verification

To verify that the device is available from the virtual machine, run the following command, substituting `<device_name>` with the `deviceName` value from the `VirtualMachine` manifest:

```
$ lspci -nnk | grep <device_name>
```

8.15.12.6. Additional resources

- Enabling Intel VT-X and AMD-V Virtualization Hardware Extensions in BIOS

8.15.13. Configuring a watchdog

Expose a watchdog by configuring the virtual machine (VM) for a watchdog device, installing the watchdog, and starting the watchdog service.

8.15.13.1. Prerequisites

- The virtual machine must have kernel support for an `i6300esb` watchdog device. Red Hat Enterprise Linux (RHEL) images support `i6300esb`.

8.15.13.2. Defining a watchdog device

Define how the watchdog proceeds when the operating system (OS) no longer responds.

Table 8.5. Available actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>poweroff</td>
<td>The virtual machine (VM) powers down immediately. If <code>spec.running</code> is set to <code>true</code>, or <code>spec.runStrategy</code> is not set to <code>manual</code>, then the VM reboots.</td>
</tr>
<tr>
<td>reset</td>
<td>The VM reboots in place and the guest OS cannot react. Because the length of time required for the guest OS to reboot can cause liveness probes to timeout, use of this option is discouraged. This timeout can extend the time it takes the VM to reboot if cluster-level protections notice the liveness probe failed and forcibly reschedule it.</td>
</tr>
<tr>
<td>shutdown</td>
<td>The VM gracefully powers down by stopping all services.</td>
</tr>
</tbody>
</table>

Procedure

1. Create a YAML file with the following contents:

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  labels:
    kubevirt.io/vm: vm2-rhel84-watchdog
name: <vm-name>
spec:
  running: false
  template:
    metadata:
      labels:
```
Specify the `watchdog` action (**poweroff**, **reset**, or **shutdown**).

The example above configures the **i6300esb** watchdog device on a RHEL8 VM with the poweroff action and exposes the device as `/dev/watchdog`.

This device can now be used by the `watchdog` binary.

2. Apply the YAML file to your cluster by running the following command:

   ```
   $ oc apply -f <file_name>.yaml
   ```

   **IMPORTANT**

   This procedure is provided for testing watchdog functionality only and must not be run on production machines.

   1. Run the following command to verify that the VM is connected to the watchdog device:

   ```
   $ lspci | grep watchdog -i
   ```

   2. Run one of the following commands to confirm the watchdog is active:

   - Trigger a kernel panic:
     ```
     # echo c > /proc/sysrq-trigger
     ```
   - Terminate the watchdog service:
     ```
     # pkill -9 watchdog
     ```

### 8.15.13.3. Installing a watchdog device

Install the `watchdog` package on your virtual machine and start the watchdog service.

**Procedure**

1. As a root user, install the `watchdog` package and dependencies:

   ```
   # yum install watchdog
   ```

2. Uncomment the following line in the `/etc/watchdog.conf` file, and save the changes:
Enable the watchdog service to start on boot:

```bash
# systemctl enable --now watchdog.service
```

### 8.15.13.4. Additional resources

- Monitoring application health by using health checks

### 8.15.14. Automatic importing and updating of pre-defined boot sources

As of version 4.10, OpenShift Virtualization automatically imports and updates pre-defined boot sources, unless you manually opt-out. If you upgrade to version OpenShift Virtualization 4.10 from version 4.9 or earlier and have pre-defined boot sources from the earlier version, you must manually opt-in to automatic imports and updates for those pre-defined boot sources.

#### 8.15.14.1. Enabling automatic boot source updates

If you have pre-defined boot sources from OpenShift Virtualization 4.9, then you must manually opt them in to the automatic boot source updates. All pre-defined boot sources from OpenShift Virtualization 4.10 and later are automatically updated by default.

**Procedure**

- Use the following command to apply the `dataImportCron` label to the data source:

  ```bash
  $ oc label --overwrite DataSource rhel8 -n openshift-virtualization-os-images
cdi.kubevirt.io/dataImportCron=true
  ```

#### 8.15.14.2. Disabling automatic boot source updates

You can reduce the number of logs on disconnected environments or reduce resource usage by disabling the automatic imports and updates of pre-defined boot sources. Set the `spec.featureGates.enableCommonBootImageImport` field in the `HyperConverged` custom resource (CR) to `false`.

**NOTE**

Custom boot sources are not affected by this setting.

**Procedure**

- Use the following command to disable automatic updates:

  ```bash
  $ oc patch hco kubevirt-hyperconverged -n openshift-cnv --type json -p '[{"op": "replace",
  "path": "/spec/featureGates/enableCommonBootImageImport", "value": false}]'
  ```

#### 8.15.14.3. Re-enabling automatic boot source updates
If you have previously disabled automatic boot source updates, you must manually re-enable the feature. Set the `spec.featureGates.enableCommonBootImageImport` field in the `HyperConverged` custom resource (CR) to `true`.

**Procedure**

- Use the following command to re-enable automatic updates:

  ```
  $ oc patch hco kubevirt-hyperconverged -n openshift-cnv --type json -p '[["op": "replace", "path": "/spec/featureGates/enableCommonBootImageImport", "value": true]]'
  ```

**8.15.14.4. Enabling automatic updates on custom boot sources**

OpenShift Virtualization automatically updates pre-defined boot sources by default, but does not automatically update custom boot sources. You must manually enable automatic imports and updates on any custom boot sources by editing the `HyperConverged` custom resource (CR).

**Procedure**

1. Use the following command to open the `HyperConverged` CR for editing:

   ```
   $ oc edit -n openshift-cnv HyperConverged
   ```

2. Edit the `HyperConverged` CR, specifying the appropriate template and boot source in the `dataImportCronTemplates` section. For example:

**Example in CentOS 7**

```yaml
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
spec:
dataImportCronTemplates:
- metadata:
  name: centos7-image-cron
  annotations:
    cdi.kubevirt.io/storage.bind.immediate.requested: "true"  
spec:
schedule: "0 */12 * * *"  
template:
  spec:
    source:
      registry:  
      storage:
        resources:
          requests:
            storage: 10Gi
      managedDataSource: centos7  
    retentionPolicy: "None"  
```
This annotation is required for storage classes with `volumeBindingMode` set to `WaitForFirstConsumer`.

Schedule for the job specified in cron format.

Use to create a data volume from a registry source. Use the default `pod pullMethod` and not `node pullMethod`, which is based on the `node` docker cache. The `node` docker cache is useful when a registry image is available via `Container.Image`, but the CDI importer is not authorized to access it.

For the custom image to be detected as an available boot source, the name of the image’s `managedDataSource` must match the name of the template’s `DataSource`, which is found under `spec.dataVolumeTemplates.spec.sourceRef.name` in the VM template YAML file.

Use `All` to retain data volumes and data sources when the cron job is deleted. Use `None` to delete data volumes and data sources when the cron job is deleted.

### 8.15.15. Enabling descheduler evictions on virtual machines

**IMPORTANT**

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

For more information about the support scope of Red Hat Technology Preview features, see [https://access.redhat.com/support/offerings/techpreview/](https://access.redhat.com/support/offerings/techpreview/).

The descheduler can be used to evict a running pod to allow the pod to be rescheduled onto a more suitable node. You must install the descheduler by using the OpenShift Container Platform web console or OpenShift CLI (`oc`) before you can enable it on your virtual machine (VM).

#### 8.15.15.1. Descheduler profiles

Use the Technology Preview `DevPreviewLongLifecycle` profile to enable the descheduler on a virtual machine. This is the only descheduler profile currently available for OpenShift Virtualization. To ensure proper scheduling, create VMs with CPU and memory requests for the expected load.

**DevPreviewLongLifecycle**

This profile balances resource usage between nodes and enables the following strategies:

- **RemovePodsHavingTooManyRestarts**: removes pods whose containers have been restarted too many times and pods where the sum of restarts over all containers (including Init Containers) is more than 100. Restarting the VM guest operating system does not increase this count.

- **LowNodeUtilization**: evicts pods from overutilized nodes when there are any underutilized nodes. The destination node for the evicted pod will be determined by the scheduler.
  - A node is considered underutilized if its usage is below 20% for all thresholds (CPU, memory, and number of pods).
A node is considered overutilized if its usage is above 50% for any of the thresholds (CPU, memory, and number of pods).

8.15.15.2. Installing the descheduler

The descheduler is not available by default. To enable the descheduler, you must install the Kube Descheduler Operator from OperatorHub and enable one or more descheduler profiles.

Prerequisites

- Cluster administrator privileges.
- Access to the OpenShift Container Platform web console.

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Create the required namespace for the Kube Descheduler Operator.
   a. Navigate to Administration → Namespaces and click Create Namespace.
   b. Enter openshift-kube-descheduler-operator in the Name field, enter openshift.io/cluster-monitoring=true in the Labels field to enable descheduler metrics, and click Create.
3. Install the Kube Descheduler Operator.
   a. Navigate to Operators → OperatorHub.
   b. Type Kube Descheduler Operator into the filter box.
   c. Select the Kube Descheduler Operator and click Install.
   d. On the Install Operator page, select A specific namespace on the cluster Select openshift-kube-descheduler-operator from the drop-down menu.
   e. Adjust the values for the Update Channel and Approval Strategy to the desired values.
   f. Click Install.
4. Create a descheduler instance.
   a. From the Operators → Installed Operators page, click the Kube Descheduler Operator.
   b. Select the Kube Descheduler tab and click Create KubeDescheduler.
   c. Edit the settings as necessary.
      i. Expand the Profiles section and select DevPreviewLongLifecycle. The AffinityAndTaints profile is enabled by default.

IMPORTANT

The only profile currently available for OpenShift Virtualization is DevPreviewLongLifecycle.
You can also configure the profiles and settings for the descheduler later using the OpenShift CLI (`oc`).

### 8.15.15.3. Enabling descheduler evictions on a virtual machine (VM)

After the descheduler is installed, you can enable descheduler evictions on your VM by adding an annotation to the VirtualMachine custom resource (CR).

**Prerequisites**

- Install the descheduler in the OpenShift Container Platform web console or OpenShift CLI (`oc`).
- Ensure that the VM is not running.

**Procedure**

1. Before starting the VM, add the `descheduler.alpha.kubernetes.io/evict` annotation to the VirtualMachine CR:

   ```yaml
   apiVersion: kubevirt.io/v1
   kind: VirtualMachine
   spec:
     template:
       metadata:
         annotations:
           descheduler.alpha.kubernetes.io/evict: "true"
   ```

2. If you did not already set the `DevPreviewLongLifecycle` profile in the web console during installation, specify the `DevPreviewLongLifecycle` in the `spec.profile` section of the KubeDescheduler object:

   ```yaml
   apiVersion: operator.openshift.io/v1
   kind: KubeDescheduler
   metadata:
     name: cluster
   namespace: openshift-kube-descheduler-operator
   spec:
     deschedulingIntervalSeconds: 3600
     profiles:
     - DevPreviewLongLifecycle
   ```

The descheduler is now enabled on the VM.

### 8.16. IMPORTING VIRTUAL MACHINES

### 8.16.1. TLS certificates for data volume imports

#### 8.16.1.1. Adding TLS certificates for authenticating data volume imports

TLS certificates for registry or HTTPS endpoints must be added to a config map to import data from these sources. This config map must be present in the namespace of the destination data volume.

Create the config map by referencing the relative file path for the TLS certificate.
Procedure

1. Ensure you are in the correct namespace. The config map can only be referenced by data volumes if it is in the same namespace.

   $ oc get ns

2. Create the config map:

   $ oc create configmap <configmap-name> --from-file=/path/to/file/ca.pem

8.16.1.2. Example: Config map created from a TLS certificate

The following example is of a config map created from ca.pem TLS certificate.

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: tls-certs
data:
  ca.pem: |
    -----BEGIN CERTIFICATE-----
    ...
    <base64 encoded cert>
    ...
    -----END CERTIFICATE-----
```

8.16.2. Importing virtual machine images with data volumes

Use the Containerized Data Importer (CDI) to import a virtual machine image into a persistent volume claim (PVC) by using a data volume. You can attach a data volume to a virtual machine for persistent storage.

The virtual machine image can be hosted at an HTTP or HTTPS endpoint, or built into a container disk and stored in a container registry.

**IMPORTANT**

When you import a disk image into a PVC, the disk image is expanded to use the full storage capacity that is requested in the PVC. To use this space, the disk partitions and file system(s) in the virtual machine might need to be expanded.

The resizing procedure varies based on the operating system installed on the virtual machine. See the operating system documentation for details.

8.16.2.1. Prerequisites

- If the endpoint requires a TLS certificate, the certificate must be included in a config map in the same namespace as the data volume and referenced in the data volume configuration.
- To import a container disk:
  - You might need to prepare a container disk from a virtual machine image and store it in your container registry before importing it.
If the container registry does not have TLS, you must add the registry to the `insecureRegistries` field of the `HyperConverged` custom resource before you can import a container disk from it.

- You might need to define a storage class or prepare CDI scratch space for this operation to complete successfully.

### 8.16.2.2. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
<thead>
<tr>
<th>Content types</th>
<th>HTTP</th>
<th>HTTPS</th>
<th>HTTP basic auth</th>
<th>Registry</th>
<th>Upload</th>
</tr>
</thead>
<tbody>
<tr>
<td>KubeVirt (QCOW2)</td>
<td>✓ QCOW2</td>
<td>✓ QCOW2**</td>
<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td></td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td></td>
</tr>
</tbody>
</table>

- Supported operation
- Unsupported operation
- * Requires scratch space
- ** Requires scratch space if a custom certificate authority is required

**NOTE**

CDI now uses the OpenShift Container Platform cluster-wide proxy configuration.

### 8.16.2.3. About data volumes

**DataVolume** objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

### 8.16.2.4. Importing a virtual machine image into a persistent volume claim by using a data volume

You can import a virtual machine image into a persistent volume claim (PVC) by using a data volume.

The virtual machine image can be hosted at an HTTP or HTTPS endpoint, or the image can be built into a container disk and stored in a container registry.

To create a virtual machine from an imported virtual machine image, specify the image or container disk endpoint in the `VirtualMachine` configuration file before you create the virtual machine.
Prerequisites

- You have installed the OpenShift CLI (oc).
- Your cluster has at least one available persistent volume.
- To import a virtual machine image you must have the following:
  - A virtual machine disk image in RAW, ISO, or QCOW2 format, optionally compressed by using xz or gz.
  - An HTTP endpoint where the image is hosted, along with any authentication credentials needed to access the data source. For example: http://www.example.com/path/to/data
- To import a container disk you must have the following:
  - A container disk built from a virtual machine image stored in your container image registry, along with any authentication credentials needed to access the data source. For example: docker://registry.example.com/container-image

Procedure

1. Optional: If your data source requires authentication credentials, edit the endpoint-secret.yaml file, and apply the updated configuration to the cluster:

   ```yaml
   apiVersion: v1
   kind: Secret
   metadata:
     name: <endpoint-secret>
     labels:
       app: containerized-data-importer
       type: Opaque
   data:
     accessKeyId: ""  # Optional: your key or user name, base64 encoded
     secretKey: ""  # Optional: your secret or password, base64 encoded
   
   $ oc apply -f endpoint-secret.yaml
   
   1 Optional: your key or user name, base64 encoded
   2 Optional: your secret or password, base64 encoded
   
2. Edit the virtual machine configuration file, specifying the data source for the virtual machine image you want to import. In this example, a Fedora image is imported from an http source:

   ```yaml
   apiVersion: kubevirt.io/v1
   kind: VirtualMachine
   metadata:
     creationTimestamp: null
   labels:
     kubevirt.io/vm: vm-fedora-datavolume
   name: vm-fedora-datavolume
   spec:
     dataVolumeTemplates:
     - metadata:
   ```
The source type to import the image from. This example uses an HTTP endpoint. To import a container disk from a registry, replace **http** with **registry**.

The source of the virtual machine image you want to import. This example references a virtual machine image at an HTTP endpoint. An example of a container registry endpoint is **url: "docker://kubevirt/fedora-cloud-container-disk-demo:latest"**.

The **secretRef** parameter is optional.

The **certConfigMap** is required for communicating with servers that use self-signed certificates or certificates not signed by the system CA bundle. The referenced config map must be in the same namespace as the data volume.
Specify type: `dataVolume` or type: `""`. If you specify any other value for type, such as `persistentVolumeClaim`, a warning is displayed, and the virtual machine does not start.

3. Create the virtual machine:

   ```bash
   $ oc create -f vm-<name>-datavolume.yaml
   ```

   **NOTE**
   
   The `oc create` command creates the data volume and the virtual machine. The CDI controller creates an underlying PVC with the correct annotation, and the import process begins. When the import completes, the data volume status changes to `Succeeded`, and the virtual machine is allowed to start.

   Data volume provisioning happens in the background, so there is no need to monitor it. You can start the virtual machine, and it will not run until the import is complete.

### Verification

1. The importer pod downloads the virtual machine image or container disk from the specified URL and stores it on the provisioned PV. View the status of the importer pod by running the following command:

   ```bash
   $ oc get pods
   ```

2. Monitor the data volume status until it shows `Succeeded` by running the following command:

   ```bash
   $ oc describe dv <datavolume-name>
   ```

   The name of the data volume as specified under `dataVolumeTemplates.metadata.name` in the virtual machine configuration file. In the example configuration above, this is `fedora-dv`.

3. To verify that provisioning is complete and that the VMI has started, try accessing its serial console by running the following command:

   ```bash
   $ virtctl console <vm-fedora-datavolume>
   ```

#### 8.16.2.5. Additional resources

- Configure preallocation mode to improve write performance for data volume operations.

#### 8.16.3. Importing virtual machine images to block storage with data volumes

You can import an existing virtual machine image into your OpenShift Container Platform cluster. OpenShift Virtualization uses data volumes to automate the import of data and the creation of an underlying persistent volume claim (PVC).
IMPORTANT

When you import a disk image into a PVC, the disk image is expanded to use the full storage capacity that is requested in the PVC. To use this space, the disk partitions and file system(s) in the virtual machine might need to be expanded.

The resizing procedure varies based on the operating system that is installed on the virtual machine. See the operating system documentation for details.

8.16.3.1. Prerequisites

- If you require scratch space according to the CDI supported operations matrix, you must first define a storage class or prepare CDI scratch space for this operation to complete successfully.

8.16.3.2. About data volumes

DataVolume objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.16.3.3. About block persistent volumes

A block persistent volume (PV) is a PV that is backed by a raw block device. These volumes do not have a file system and can provide performance benefits for virtual machines by reducing overhead.

Raw block volumes are provisioned by specifying `volumeMode: Block` in the PV and persistent volume claim (PVC) specification.

8.16.3.4. Creating a local block persistent volume

Create a local block persistent volume (PV) on a node by populating a file and mounting it as a loop device. You can then reference this loop device in a PV manifest as a Block volume and use it as a block device for a virtual machine image.

Procedure

1. Log in as root to the node on which to create the local PV. This procedure uses node01 for its examples.

2. Create a file and populate it with null characters so that it can be used as a block device. The following example creates a file loop10 with a size of 2Gb (20 100Mb blocks):

   ```
   $ dd if=/dev/zero of=<loop10> bs=100M count=20
   $$ losetup </dev/loop10>d3 <loop10>
   ```

3. Mount the loop10 file as a loop device.

   ```
   $ losetup </dev/loop10>d3 <loop10> 1 2
   ```

   1. File path where the loop device is mounted.
   2. The file created in the previous step to be mounted as the loop device.
4. Create a **PersistentVolume** manifest that references the mounted loop device.

```yaml
kind: PersistentVolume
apiVersion: v1
metadata:
  name: <local-block-pv10>
  annotations:
  spec:
    local:
      path: </dev/loop10>  
      capacity:
        storage: <2Gi>
      volumeMode: Block
    storageClassName: local
    accessModes:
      - ReadWriteOnce
    persistentVolumeReclaimPolicy: Delete
    nodeAffinity:
      required:
        nodeSelectorTerms:
          - matchExpressions:
            - key: kubernetes.io/hostname
              operator: In
            values:
              - <node01>

1. The path of the loop device on the node.
2. Specifies it is a block PV.
3. Optional: Set a storage class for the PV. If you omit it, the cluster default is used.
4. The node on which the block device was mounted.

5. Create the block PV.

```
oc create -f <local-block-pv10.yaml>```

1. The file name of the persistent volume created in the previous step.

### 8.16.3.5. Importing a virtual machine image to a block persistent volume using data volumes

You can import an existing virtual machine image into your OpenShift Container Platform cluster. OpenShift Virtualization uses data volumes to automate the importing data and the creation of an underlying persistent volume claim (PVC). You can then reference the data volume in a virtual machine manifest.

**Prerequisites**

- A virtual machine disk image, in RAW, ISO, or QCOW2 format, optionally compressed by using `xz` or `gz`
An **HTTP** or **s3** endpoint where the image is hosted, along with any authentication credentials needed to access the data source

- At least one available block PV.

### Procedure

1. If your data source requires authentication credentials, edit the `endpoint-secret.yaml` file, and apply the updated configuration to the cluster.
   a. Edit the `endpoint-secret.yaml` file with your preferred text editor:

   ```yaml
   apiVersion: v1
   kind: Secret
   metadata:
     name: <endpoint-secret>
     labels:
       app: containerized-data-importer
       type: Opaque
   data:
     accessKeyId: "" 1
     secretKey: "" 2
   
   1 Optional: your key or user name, base64 encoded
   2 Optional: your secret or password, base64 encoded
   
   b. Update the secret by running the following command:

   ```sh
cd $HOME/your-app
$ oc apply -f endpoint-secret.yaml
```

2. Create a **DataVolume** manifest that specifies the data source for the image you want to import and **volumeMode: Block** so that an available block PV is used.

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: <import-pv-datavolume> 1
spec:
  storageClassName: local 2
  source:
    http:
      url: <http://download.fedoraproject.org/pub/fedora/linux/releases/28/Cloud/x86_64/images/Fedora-Cloud-Base-28-1.1.x86_64.qcow2> 3
      secretRef: <endpoint-secret> 4
  pvc:
    volumeMode: Block 5
    accessModes:
      - ReadWriteOnce
    resources:
      requests:
        storage: <2Gi>
```
The name of the data volume.

Optional: Set the storage class or omit it to accept the cluster default.

The **HTTP** source of the image to import.

Only required if the data source requires authentication.

Required for importing to a block PV.

3. Create the data volume to import the virtual machine image by running the following command:

```
$ oc create -f <import-pv-datavolume.yaml>
```

The file name of the data volume that you created in the previous step.

8.16.3.6. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
<thead>
<tr>
<th>Content types</th>
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<td>✓ QCOW2 ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2* □ GZ □ XZ</td>
<td>✓ QCOW2* ✓ GZ* ✓ XZ*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW* □ GZ □ XZ</td>
<td>✓ RAW* ✓ GZ* ✓ XZ*</td>
</tr>
</tbody>
</table>

✓ Supported operation

□ Unsupported operation

* Requires scratch space

** Requires scratch space if a custom certificate authority is required

**NOTE**

CDI now uses the OpenShift Container Platform **cluster-wide proxy configuration**.

8.16.3.7. Additional resources

- Configure preallocation mode to improve write performance for data volume operations.

8.17. CLONING VIRTUAL MACHINES
8.17.1. Enabling user permissions to clone data volumes across namespaces

The isolating nature of namespaces means that users cannot by default clone resources between namespaces.

To enable a user to clone a virtual machine to another namespace, a user with the \texttt{cluster-admin} role must create a new cluster role. Bind this cluster role to a user to enable them to clone virtual machines to the destination namespace.

8.17.1.1. Prerequisites

- Only a user with the \texttt{cluster-admin} role can create cluster roles.

8.17.1.2. About data volumes

\texttt{DataVolume} objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.17.1.3. Creating RBAC resources for cloning data volumes

Create a new cluster role that enables permissions for all actions for the \texttt{datavolumes} resource.

Procedure

1. Create a \texttt{ClusterRole} manifest:

   ```yaml
   apiVersion: rbac.authorization.k8s.io/v1
   kind: ClusterRole
   metadata:
     name: <datavolume-cloner>
   rules:
     - apiGroups: ["cdi.kubevirt.io"]
       resources: ["datavolumes/source"]
       verbs: ["*"]
   ```

   Unique name for the cluster role.

2. Create the cluster role in the cluster:

   ```bash
   $ oc create -f <datavolume-cloner.yaml>
   ```

   The file name of the \texttt{ClusterRole} manifest created in the previous step.

3. Create a \texttt{RoleBinding} manifest that applies to both the source and destination namespaces and references the cluster role created in the previous step.

   ```yaml
   apiVersion: rbac.authorization.k8s.io/v1
   kind: RoleBinding
   metadata:
     name: <allow-clone-to-user>
   ```
namespace: <Source namespace>
subjects:
- kind: ServiceAccount
  name: default
  namespace: <Destination namespace>
roleRef:
  kind: ClusterRole
  name: datavolume-cloner
  apiGroup: rbac.authorization.k8s.io

4. Create the role binding in the cluster:

$ oc create -f <datavolume-cloner.yaml>

The file name of the RoleBinding manifest created in the previous step.

8.17.2. Cloning a virtual machine disk into a new data volume

You can clone the persistent volume claim (PVC) of a virtual machine disk into a new data volume by referencing the source PVC in your data volume configuration file.

**WARNING**

Cloning operations between different volume modes are supported, such as cloning from a persistent volume (PV) with `volumeMode: Block` to a PV with `volumeMode: Filesystem`.

However, you can only clone between different volume modes if they are of the `contentType: kubevirt`.

**TIP**

When you enable preallocation globally, or for a single data volume, the Containerized Data Importer (CDI) preallocates disk space during cloning. Preallocation enhances write performance. For more information, see [Using preallocation for data volumes](#).

8.17.2.1. Prerequisites

- Users need additional permissions to clone the PVC of a virtual machine disk into another namespace.
8.17.2.2. About data volumes

**DataVolume** objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.17.2.3. Cloning the persistent volume claim of a virtual machine disk into a new data volume

You can clone a persistent volume claim (PVC) of an existing virtual machine disk into a new data volume. The new data volume can then be used for a new virtual machine.

**NOTE**

When a data volume is created independently of a virtual machine, the lifecycle of the data volume is independent of the virtual machine. If the virtual machine is deleted, neither the data volume nor its associated PVC is deleted.

**Prerequisites**

- Determine the PVC of an existing virtual machine disk to use. You must power down the virtual machine that is associated with the PVC before you can clone it.
- Install the OpenShift CLI (**oc**).

**Procedure**

1. Examine the virtual machine disk you want to clone to identify the name and namespace of the associated PVC.

2. Create a YAML file for a data volume that specifies the name of the new data volume, the name and namespace of the source PVC, and the size of the new data volume. For example:

   ```yaml
   apiVersion: cdi.kubevirt.io/v1beta1
   kind: DataVolume
   metadata:
     name: <cloner-datavolume> 1
   spec:
     source:
       pvc:
         namespace: "<source-namespace>" 2
         name: "<my-favorite-vm-disk>" 3
       accessModes:
         - ReadWriteOnce
       resources:
         requests:
           storage: <2Gi> 4
   
   1 The name of the new data volume.
   2 The namespace where the source PVC exists.
   ```
The name of the source PVC.

The size of the new data volume. You must allocate enough space, or the cloning operation fails. The size must be the same as or larger than the source PVC.

3. Start cloning the PVC by creating the data volume:

```
$ oc create -f <cloner-datavolume>.yaml
```

**NOTE**

Data volumes prevent a virtual machine from starting before the PVC is prepared, so you can create a virtual machine that references the new data volume while the PVC clones.

### 8.17.2.4. Template: Data volume clone configuration file

**example-clone-dv.yaml**

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: "example-clone-dv"
spec:
  source:
    pvc:
      name: source-pvc
      namespace: example-ns
  resources:
    requests:
      storage: "1G"
```

### 8.17.2.5. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
<thead>
<tr>
<th>Content types</th>
<th>HTTP</th>
<th>HTTPS</th>
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</tr>
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<tbody>
<tr>
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<td>✓ QCOW2**</td>
<td>✓ QCOW2</td>
<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
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</tr>
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<td>✓ QCOW2</td>
<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
</tr>
</tbody>
</table>

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<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
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<td>✓ RAW</td>
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<td>✓ RAW</td>
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<td>✓ QCOW2</td>
<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
</tr>
</tbody>
</table>
8.17.3. Cloning a virtual machine by using a data volume template

You can create a new virtual machine by cloning the persistent volume claim (PVC) of an existing VM. By including a `dataVolumeTemplate` in your virtual machine configuration file, you create a new data volume from the original PVC.

**WARNING**

Cloning operations between different volume modes are supported, such as cloning from a persistent volume (PV) with `volumeMode: Block` to a PV with `volumeMode: Filesystem`.

However, you can only clone between different volume modes if they are of the `contentType: kubevirt`.

**TIP**

When you enable preallocation globally, or for a single data volume, the Containerized Data Importer (CDI) preallocates disk space during cloning. Preallocation enhances write performance. For more information, see [Using preallocation for data volumes](#).

8.17.3.1. Prerequisites

- Users need additional permissions to clone the PVC of a virtual machine disk into another namespace.

8.17.3.2. About data volumes

`DataVolume` objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.17.3.3. Creating a new virtual machine from a cloned persistent volume claim by using a data volume template

You can create a virtual machine that clones the persistent volume claim (PVC) of an existing virtual machine into a data volume. Reference a `dataVolumeTemplate` in the virtual machine manifest and the source PVC is cloned to a data volume, which is then automatically used for the creation of the virtual machine.
When a data volume is created as part of the data volume template of a virtual machine, the lifecycle of the data volume is then dependent on the virtual machine. If the virtual machine is deleted, the data volume and associated PVC are also deleted.

**Prerequisites**

- Determine the PVC of an existing virtual machine disk to use. You must power down the virtual machine that is associated with the PVC before you can clone it.

- Install the OpenShift CLI (`oc`).

**Procedure**

1. Examine the virtual machine you want to clone to identify the name and namespace of the associated PVC.

2. Create a YAML file for a `VirtualMachine` object. The following virtual machine example clones `my-favorite-vm-disk`, which is located in the `source-namespace` namespace. The 2Gi data volume called `favorite-clone` is created from `my-favorite-vm-disk`.

   For example:

   ```yaml
   apiVersion: kubevirt.io/v1
   kind: VirtualMachine
   metadata:
     labels:
       kubevirt.io/vm: vm-dv-clone
   name: vm-dv-clone
   spec:
     running: false
     template:
       metadata:
         labels:
           kubevirt.io/vm: vm-dv-clone
       spec:
         domain:
           devices:
             disks:
               - disk:
                 bus: virtio
                 name: root-disk
           resources:
             requests:
               memory: 64M
         volumes:
           - dataVolume:
             name: favorite-clone
             name: root-disk
           dataVolumeTemplates:
             - metadata:
               name: favorite-clone
             spec:
               pvc:
                 accessModes:
               ```
3. Create the virtual machine with the PVC-cloned data volume:

$$\texttt{oc create -f <vm-clone-datavolumetemplate>.yaml}$$

### 8.17.3.4. Template: Data volume virtual machine configuration file

eexample-dv-vm.yaml

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  labels:
    kubevirt.io/vm: example-vm
name: example-vm
spec:
dataVolumeTemplates:
- metadata:
  name: example-dv
spec:
pvc:
  accessModes:
  -ReadWriteOnce
resources:
  requests:
    storage: 1G
source:
  http:
    url: 
running: false
template:
metadata:
  labels:
    kubevirt.io/vm: example-vm
spec:
domain:
cpu:
  cores: 1
devices:
disks:
  - disk:
    bus: virtio
    name: example-dv-disk
machine:
```
8.17.3.5. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
<thead>
<tr>
<th>Content types</th>
<th>HTTP</th>
<th>HTTPS</th>
<th>HTTP basic auth</th>
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</tr>
</thead>
<tbody>
<tr>
<td>KubeVirt (QCOW2)</td>
<td>✓ QCOW2 ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2** ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2 ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2* □ GZ □ XZ</td>
<td>✓ QCOW2* ✓ GZ* ✓ XZ*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW* □ GZ □ XZ</td>
<td>✓ RAW* ✓ GZ* ✓ XZ*</td>
</tr>
</tbody>
</table>

✓ Supported operation

□ Unsupported operation

* Requires scratch space

** Requires scratch space if a custom certificate authority is required

8.17.4. Cloning a virtual machine disk into a new block storage data volume

You can clone the persistent volume claim (PVC) of a virtual machine disk into a new block data volume by referencing the source PVC in your data volume configuration file.
Cloning operations between different volume modes are supported, such as cloning from a persistent volume (PV) with `volumeMode: Block` to a PV with `volumeMode: Filesystem`.

However, you can only clone between different volume modes if they are of the `contentType: kubevirt`.

**TIP**

When you enable preallocation globally, or for a single data volume, the Containerized Data Importer (CDI) preallocates disk space during cloning. Preallocation enhances write performance. For more information, see [Using preallocation for data volumes](#).

### 8.17.4.1. Prerequisites

- Users need additional permissions to clone the PVC of a virtual machine disk into another namespace.

### 8.17.4.2. About data volumes

**DataVolume** objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

### 8.17.4.3. About block persistent volumes

A block persistent volume (PV) is a PV that is backed by a raw block device. These volumes do not have a file system and can provide performance benefits for virtual machines by reducing overhead.

Raw block volumes are provisioned by specifying `volumeMode: Block` in the PV and persistent volume claim (PVC) specification.

### 8.17.4.4. Creating a local block persistent volume

Create a local block persistent volume (PV) on a node by populating a file and mounting it as a loop device. You can then reference this loop device in a PV manifest as a **Block** volume and use it as a block device for a virtual machine image.

**Procedure**

1. Log in as `root` to the node on which to create the local PV. This procedure uses `node01` for its examples.

2. Create a file and populate it with null characters so that it can be used as a block device. The following example creates a file `loop10` with a size of 2Gb (20 100Mb blocks):

   ```bash
   $ dd if=/dev/zero of=<loop10> bs=100M count=20
   ```
3. Mount the **loop10** file as a loop device.

   ```
   $ losetup -d /dev/loop10
   ```

   1. File path where the loop device is mounted.
   2. The file created in the previous step to be mounted as the loop device.

4. Create a **PersistentVolume** manifest that references the mounted loop device.

   ```yaml
   kind: PersistentVolume
   apiVersion: v1
   metadata:
     name: <local-block-pv10>
     annotations:
     spec:
       local:
         path: /dev/loop10
         capacity:
           storage: <2Gi>
         volumeMode: Block
       storageClassName: local
       accessModes:
         - ReadWriteOnce
       persistentVolumeReclaimPolicy: Delete
       nodeAffinity:
         required:
           nodeSelectorTerms:
             - matchExpressions:
               - key: kubernetes.io/hostname
                 operator: In
               values:
                 - <node01>
   ```

   1. The path of the loop device on the node.
   2. Specifies it is a block PV.
   3. Optional: Set a storage class for the PV. If you omit it, the cluster default is used.
   4. The node on which the block device was mounted.

5. Create the block PV.

   ```
   # oc create -f <local-block-pv10.yaml>
   ```

   1. The file name of the persistent volume created in the previous step.

8.17.4.5. Cloning the persistent volume claim of a virtual machine disk into a new data volume
You can clone a persistent volume claim (PVC) of an existing virtual machine disk into a new data volume. The new data volume can then be used for a new virtual machine.

**NOTE**

When a data volume is created independently of a virtual machine, the lifecycle of the data volume is independent of the virtual machine. If the virtual machine is deleted, neither the data volume nor its associated PVC is deleted.

**Prerequisites**

- Determine the PVC of an existing virtual machine disk to use. You must power down the virtual machine that is associated with the PVC before you can clone it.
- Install the OpenShift CLI (`oc`).
- At least one available block persistent volume (PV) that is the same size as or larger than the source PVC.

**Procedure**

1. Examine the virtual machine disk you want to clone to identify the name and namespace of the associated PVC.

2. Create a YAML file for a data volume that specifies the name of the new data volume, the name and namespace of the source PVC, `volumeMode: Block` so that an available block PV is used, and the size of the new data volume. For example:

   ```yaml
   apiVersion: cdi.kubevirt.io/v1beta1
   kind: DataVolume
   metadata:
     name: <cloner-datavolume>  
   spec:
     source:
       pvc:
         namespace: "<source-namespace>"  
         name: "<my-favorite-vm-disk>"
     pvc:
       accessModes:
         - ReadWriteOnce
       resources:
         requests:
           storage: <2Gi>
       volumeMode: Block
   
   1. The name of the new data volume.
   2. The namespace where the source PVC exists.
   3. The name of the source PVC.
   4. The size of the new data volume. You must allocate enough space, or the cloning operation fails. The size must be the same as or larger than the source PVC.
3. Start cloning the PVC by creating the data volume:

```
$ oc create -f <cloner-datavolume>.yaml
```

**NOTE**

Data volumes prevent a virtual machine from starting before the PVC is prepared, so you can create a virtual machine that references the new data volume while the PVC clones.

### 8.17.4.6. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
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<th>Content types</th>
<th>HTTP</th>
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</tr>
<tr>
<td></td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>□ GZ</td>
<td>□ QCOW2*</td>
</tr>
<tr>
<td></td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>□ XZ</td>
<td>□ QCOW2*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
</tr>
<tr>
<td></td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>□ GZ</td>
<td>□ RAW*</td>
</tr>
<tr>
<td></td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>□ XZ</td>
<td>□ RAW*</td>
</tr>
</tbody>
</table>

- ✓ Supported operation
- □ Unsupported operation
- * Requires scratch space
- ** Requires scratch space if a custom certificate authority is required

### 8.18. VIRTUAL MACHINE NETWORKING

#### 8.18.1. Using the default pod network for virtual machines

You can use the default pod network with OpenShift Virtualization. To do so, you must use the **masquerade** binding method. Do not use **masquerade** mode with non-default networks.

For secondary networks, use the **bridge** binding method.

#### 8.18.1.1. Configuring masquerade mode from the command line

You can use masquerade mode to hide a virtual machine’s outgoing traffic behind the pod IP address. Masquerade mode uses Network Address Translation (NAT) to connect virtual machines to the pod network backend through a Linux bridge.
Enable masquerade mode and allow traffic to enter the virtual machine by editing your virtual machine configuration file.

**Prerequisites**

- The virtual machine must be configured to use DHCP to acquire IPv4 addresses. The examples below are configured to use DHCP.

**Procedure**

1. Edit the `interfaces` spec of your virtual machine configuration file:

   ```yaml
   kind: VirtualMachine
   spec:
     domain:
       devices:
         interfaces:
           - name: red
             masquerade: {}
             ports: 2
               - port: 80
     networks:
       - name: red
         pod: {}
   
   1 Connect using masquerade mode
   2 Optional: List the ports that you want to expose from the virtual machine, each specified by the `port` field. The `port` value must be a number between 0 and 65536. When the `ports` array is not used, all ports in the valid range are open to incoming traffic. In this example, incoming traffic is allowed on port 80.

   **NOTE**

   Ports 49152 and 49153 are reserved for use by the libvirt platform and all other incoming traffic to these ports is dropped.

2. Create the virtual machine:

   ```bash
   $ oc create -f <vm-name>.yaml
   ```

**8.18.1.2. Configuring masquerade mode with dual-stack (IPv4 and IPv6)**

You can configure a new virtual machine (VM) to use both IPv6 and IPv4 on the default pod network by using `cloud-init`.

The `Network.pod.vmlIPv6NetworkCIDR` field in the virtual machine instance configuration determines the static IPv6 address of the VM and the gateway IP address. These are used by the `virt-launcher` pod to route IPv6 traffic to the virtual machine and are not used externally. The `Network.pod.vmlIPv6NetworkCIDR` field specifies an IPv6 address block in Classless Inter-Domain Routing (CIDR) notation. The default value is `fd10:0:2::2/120`. You can edit this value based on your network requirements.
When the virtual machine is running, incoming and outgoing traffic for the virtual machine is routed to both the IPv4 address and the unique IPv6 address of the virt-launcher pod. The virt-launcher pod then routes the IPv4 traffic to the DHCP address of the virtual machine, and the IPv6 traffic to the statically set IPv6 address of the virtual machine.

Prerequisites

- The OpenShift Container Platform cluster must use the OVN-Kubernetes Container Network Interface (CNI) network provider configured for dual-stack.

Procedure

1. In a new virtual machine configuration, include an interface with masquerade and configure the IPv6 address and default gateway by using cloud-init.

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  name: example-vm-ipv6
...
  interfaces:
    - name: red
      masquerade: {}
      ports:
        - port: 80
      networks:
        - name: red
          pod: {}
          volumes:
            - cloudInitNoCloud:
               networkData:
                version: 2
                ethernets:
                  eth0:
                    dhcp4: true
                    addresses: [ fd10:0:2::2/120 ]
                    gateway6: fd10:0:2::1

1 Connect using masquerade mode.
2 Allows incoming traffic on port 80 to the virtual machine.
3 The static IPv6 address as determined by the Network.pod.vmlPv6NetworkCIDR field in the virtual machine instance configuration. The default value is fd10:0:2::2/120.
4 The gateway IP address as determined by the Network.pod.vmlPv6NetworkCIDR field in the virtual machine instance configuration. The default value is fd10:0:2::1.

2. Create the virtual machine in the namespace:

   $ oc create -f example-vm-ipv6.yaml

Verification
- To verify that IPv6 has been configured, start the virtual machine and view the interface status of the virtual machine instance to ensure it has an IPv6 address:

```bash
$ oc get vmi <vmi-name> -o jsonpath="{.status.interfaces[*].ipAddresses[0].ipv6Addresses[0].address}"
```

### 8.18.1.3. Selecting binding method

If you create a virtual machine from the OpenShift Virtualization web console wizard, select the required binding method from the Networking screen.

#### 8.18.1.3.1. Networking fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name for the network interface controller.</td>
</tr>
<tr>
<td>Model</td>
<td>Indicates the model of the network interface controller. Supported values are e1000e and virtio.</td>
</tr>
<tr>
<td>Network</td>
<td>List of available network attachment definitions.</td>
</tr>
<tr>
<td>Type</td>
<td>List of available binding methods. For the default pod network, masquerade is the only recommended binding method. For secondary networks, use the bridge binding method. The masquerade method is not supported for non-default networks. Select SR-IOV if you configured an SR-IOV network device and defined that network in the namespace.</td>
</tr>
<tr>
<td>MAC Address</td>
<td>MAC address for the network interface controller. If a MAC address is not specified, one is assigned automatically.</td>
</tr>
</tbody>
</table>

### 8.18.1.4. Virtual machine configuration examples for the default network

#### 8.18.1.4.1. Template: Virtual machine configuration file

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  name: example-vm
  namespace: default
spec:
  running: false
  template:
    spec:
      domain:
        devices:
        disks:
          - name: containerdisk
```
CHAPTER 8. VIRTUAL MACHINES

8.18.1.4.2. Template: Windows virtual machine configuration file

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  special: vm-windows
name: vm-windows
spec:
  template:
    metadata:
      special: vm-windows
    spec:
      domain:
        clock:
          timer:
            hyperv: {}
            pit:
              tickPolicy: delay
              rtc:
                tickPolicy: catchup
            utc: {}
          cpu:
            cores: 2
        devices:
          - disk:
              bus: sata
```
8.18.1.5. Creating a service from a virtual machine

Create a service from a running virtual machine by first creating a **Service** object to expose the virtual machine.

```yaml
name: pvcdisk
interfaces:
  - masquerade: {}
model: e1000
name: default
features:
  acpi: {}
  apic: {}
  hyperv:
    relaxed: {}
    spinlocks:
      spinlocks: 8191
vapic: {}
firmware:
  uuid: 5d307ca9-b3ef-428c-8861-06e72d69f223
machine:
  type: q35
resources:
  requests:
    memory: 2Gi
networks:
  - name: default
    pod: {}
terminationGracePeriodSeconds: 3600
volumes:
  - name: pvcdisk
    persistentVolumeClaim:
      claimName: disk-windows
```
NOTE

If IPv4 and IPv6 dual-stack networking is enabled for your cluster, you can create a service that uses IPv4, IPv6, or both, by defining the `spec.ipFamilyPolicy` and the `spec.ipFamilies` fields in the `Service` object.

The `spec.ipFamilyPolicy` field can be set to one of the following values:

- **SingleStack**: The control plane assigns a cluster IP address for the service based on the first configured service cluster IP range.

- **PreferDualStack**: The control plane assigns both IPv4 and IPv6 cluster IP addresses for the service on clusters that have dual-stack configured.

- **RequireDualStack**: This option fails for clusters that do not have dual-stack networking enabled. For clusters that have dual-stack configured, the behavior is the same as when the value is set to `PreferDualStack`. The control plane allocates cluster IP addresses from both IPv4 and IPv6 address ranges.

You can define which IP family to use for single-stack or define the order of IP families for dual-stack by setting the `spec.ipFamilies` field to one of the following array values:

- `[IPv4]`
- `[IPv6]`
- `[IPv4, IPv6]`
- `[IPv6, IPv4]`

The **ClusterIP** service type exposes the virtual machine internally, within the cluster. The **NodePort** or **LoadBalancer** service types expose the virtual machine externally, outside of the cluster.

This procedure presents an example of how to create, connect to, and expose a `Service` object of type: **ClusterIP** as a virtual machine-backed service.

NOTE

**ClusterIP** is the default service type, if the service type is not specified.

Procedure

1. Edit the virtual machine YAML as follows:

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  name: vm-ephemeral
  namespace: example-namespace
spec:
  running: false
  template:
    metadata:
      labels:
        special: key
spec:
```
Add the label `special: key` in the `spec.template.metadata.labels` section.

**NOTE**

Labels on a virtual machine are passed through to the pod. The labels on the `VirtualMachine` configuration, for example `special: key`, must match the labels in the `Service` YAML `selector` attribute, which you create later in this procedure.

2. Save the virtual machine YAML to apply your changes.

3. Edit the `Service` YAML to configure the settings necessary to create and expose the `Service` object:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: vmservice
  namespace: example-namespace
spec:
  ports:
    - port: 27017
      protocol: TCP
      targetPort: 22
  selector:
    special: key
  type: ClusterIP
```

1. Add the label `special: key` in the `spec.template.metadata.labels` section.

2. Save the virtual machine YAML to apply your changes.

3. Edit the `Service` YAML to configure the settings necessary to create and expose the `Service` object:
1. Specify the name of the service you are creating and exposing.

2. Specify namespace in the metadata section of the Service YAML that corresponds to the namespace you specify in the virtual machine YAML.

3. Add targetPort: 22, exposing the service on SSH port 22.

4. In the spec section of the Service YAML, add special: key to the selector attribute, which corresponds to the labels you added in the virtual machine YAML configuration file.

5. In the spec section of the Service YAML, add type: ClusterIP for a ClusterIP service. To create and expose other types of services externally, outside of the cluster, such as NodePort and LoadBalancer, replace type: ClusterIP with type: NodePort or type: LoadBalancer, as appropriate.

4. Save the Service YAML to store the service configuration.

5. Create the ClusterIP service:

   $ oc create -f <service_name>.yaml

6. Start the virtual machine. If the virtual machine is already running, restart it.

7. Query the Service object to verify it is available and is configured with type ClusterIP.

   **Verification**

   - Run the oc get service command, specifying the namespace that you reference in the virtual machine and Service YAML files.

   $ oc get service -n example-namespace

   **Example output**

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>CLUSTER-IP</th>
<th>EXTERNAL-IP</th>
<th>PORT(S)</th>
<th>AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>vmservice</td>
<td>ClusterIP</td>
<td>172.30.3.149</td>
<td>&lt;none&gt;</td>
<td>27017/TCP</td>
<td>2m</td>
</tr>
</tbody>
</table>

   - As shown from the output, vmservice is running.

   - The TYPE displays as ClusterIP, as you specified in the Service YAML.

8. Establish a connection to the virtual machine that you want to use to back your service. Connect from an object inside the cluster, such as another virtual machine.

   a. Edit the virtual machine YAML as follows:

   ```yaml
   apiVersion: kubevirt.io/v1
   kind: VirtualMachine
   metadata:
     name: vm-connect
     namespace: example-namespace
   spec:
     running: false
   ```
b. Run the `oc create` command to create a second virtual machine, where `file.yaml` is the name of the virtual machine YAML:

```bash
$ oc create -f <file.yaml>
```

c. Start the virtual machine.

d. Connect to the virtual machine by running the following `virtctl` command:

```bash
$ virtctl -n example-namespace console <new-vm-name>
```

**NOTE**

For service type **LoadBalancer**, use the `vinagre` client to connect your virtual machine by using the public IP and port. External ports are dynamically allocated when using service type **LoadBalancer**.

e. Run the `ssh` command to authenticate the connection, where **172.30.3.149** is the ClusterIP of the service and **fedora** is the user name of the virtual machine:

```bash
$ ssh fedora@172.30.3.149 -p 27017
```

**Verification**
You receive the command prompt of the virtual machine backing the service you want to expose. You now have a service backed by a running virtual machine.

Additional resources

- Configuring external IPs
- Service API specification

8.18.2. Attaching a virtual machine to multiple networks

You can attach virtual machines to multiple networks by using Linux bridges. You can also import virtual machines with existing workloads that depend on access to multiple interfaces.

To attach a virtual machine to an additional network:

1. Configure a Linux bridge.

2. Configure a bridge network attachment definition for a namespace in the web console or CLI.

   NOTE

   The network attachment definition must be in the same namespace as the pod or virtual machine.

3. Attach the virtual machine to the network attachment definition by using either the web console or the CLI:

   - In the web console, create a NIC for a new or existing virtual machine.
   - In the CLI, include the network information in the virtual machine configuration.

   NOTE

   There are multiple methods for configuring a VLAN, including network attachment definition and node network configuration policy. However, a network attachment definition provides a more efficient and more manageable configuration.

8.18.2.1. OpenShift Virtualization networking glossary

OpenShift Virtualization provides advanced networking functionality by using custom resources and plug-ins.

The following terms are used throughout OpenShift Virtualization documentation:

- **Container Network Interface (CNI)**
  a Cloud Native Computing Foundation project, focused on container network connectivity. OpenShift Virtualization uses CNI plug-ins to build upon the basic Kubernetes networking functionality.

- **Multus**
  a "meta" CNI plug-in that allows multiple CNIs to exist so that a pod or virtual machine can use the interfaces it needs.

- **Custom resource definition (CRD)**
a Kubernetes API resource that allows you to define custom resources, or an object defined by using the CRD API resource.

**Network attachment definition (NAD)**

A CRD introduced by the Multus project that allows you to attach pods, virtual machines, and virtual machine instances to one or more networks.

**Node network configuration policy (NNCP)**

A description of the requested network configuration on nodes. You update the node network configuration, including adding and removing interfaces, by applying a `NodeNetworkConfigurationPolicy` manifest to the cluster.

**Preboot eXecution Environment (PXE)**

An interface that enables an administrator to boot a client machine from a server over the network. Network booting allows you to remotely load operating systems and other software onto the client.

### 8.18.2.2. Configuring a Linux bridge

#### 8.18.2.2.1. Creating a Linux bridge using a node network configuration policy

As a network administrator, you can create a Linux bridge interface on nodes in the cluster by applying a `NodeNetworkConfigurationPolicy` manifest to the cluster.

**Procedure**

1. Create the `NodeNetworkConfigurationPolicy` manifest. This YAML file is an example of a manifest for a Linux bridge interface. It includes samples values that you must replace with your own information.

```yaml
apiVersion: nmstate.io/v1
kind: NodeNetworkConfigurationPolicy
metadata:
  name: br1-eth1-policy
spec:
  desiredState:
    interfaces:
    - name: br1
      description: Linux bridge with eth1 as a port
      type: linux-bridge
      state: up
      ipv4:
        enabled: false
      bridge:
        options:
          stp:
            enabled: false
          port:
            - name: eth1
```

1. Name of the policy.
2. Name of the interface.
8.18.2.3. Creating a network attachment definition

**WARNING**
Configuring ipam in a network attachment definition for virtual machines is not supported.

8.18.2.3.1. Creating a Linux bridge network attachment definition in the web console

Network administrators can create network attachment definitions to provide layer-2 networking to pods and virtual machines.

**Procedure**

1. In the web console, click Networking → Network Attachment Definitions.
2. Click Create Network Attachment Definition.
3. Enter a unique Name and optional Description.
4. Click the Network Type list and select CNV Linux bridge.
5. Enter the name of the bridge in the Bridge Name field.
6. Optional: If the resource has VLAN IDs configured, enter the ID numbers in the VLAN Tag Number field.
7. Optional: Select the MAC Spoof Check checkbox to enable MAC spoof filtering. This feature provides security against a MAC spoofing attack by allowing only a single MAC address to exit the pod.
8. Click Create.

8.18.2.3.2. Creating a Linux bridge network attachment definition in the CLI

As a network administrator, you can configure a network attachment definition of type cnv-bridge to provide Layer-2 networking to pods and virtual machines.
Prerequisites

- The node must support nftables and the `nft` binary must be deployed to enable MAC spoof check.

Procedure

1. Create a network attachment definition manifest. The manifest must have the following contents, modified to match your configuration:

   ```yaml
   apiVersion: "k8s.cni.cncf.io/v1"
   kind: NetworkAttachmentDefinition
   metadata:
     name: <a-bridge-network>  # 1
     annotations:
       k8s.v1.cni.cncf.io/resourceName: bridge.network.kubevirt.io/<bridge-interface>  # 2
   spec:
     config: '{
       "cniVersion": "0.3.1",
       "name": "<a-bridge-network>",  # 3
       "type": "cnv-bridge",  # 4
       "bridge": "<bridge-interface>",  # 5
       "macspoofchk": true,  # 6
       "vlan": 1  # 7
     }
   }
   
   $ oc create -f <network-attachment-definition.yaml>  # 1
   
   The name for the **NetworkAttachmentDefinition** object.

   Optional: Annotation key-value pair for node selection, where `bridge-interface` must match the name of a bridge configured on some nodes. If you add this annotation to your network attachment definition, your virtual machine instances will only run on the nodes that have the `bridge-interface` bridge connected.

   The name for the configuration. It is recommended to match the configuration name to the `name` value of the network attachment definition.

   The actual name of the Container Network Interface (CNI) plug-in that provides the network for this network attachment definition. Do not change this field unless you want to use a different CNI.

   The name of the Linux bridge configured on the node.

   Optional: Flag to enable MAC spoof check. When set to `true`, you cannot change the MAC address of the pod or guest interface. This attribute provides security against a MAC spoofing attack by allowing only a single MAC address to exit the pod.

   Optional: The VLAN tag. No additional VLAN configuration is required on the node network configuration policy.

2. Create the network attachment definition:

   ```sh
   $ oc create -f <network-attachment-definition.yaml>
   ```
Where `<network-attachment-definition.yaml>` is the file name of the network attachment definition manifest.

**Verification**

- Verify that the network attachment definition is created by running either `oc get network-attachment-definition <name>` or `oc get net-attach-def <name>`. For example:

  ```bash
  $ oc get network-attachment-definition <a-bridge-network>
  ```

  Where `<a-bridge-network>` is the name specified in the network attachment definition config.

8.18.2.4. Attaching the virtual machine to the additional network

8.18.2.4.1. Creating a NIC for a virtual machine in the web console

Create and attach additional NICs to a virtual machine from the web console.

**Procedure**

1. In the correct project in the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** screen.

4. Click **Network Interfaces** to display the NICs already attached to the virtual machine.

5. Click **Add Network Interface** to create a new slot in the list.

6. Use the **Network** drop-down list to select the network attachment definition for the additional network.

7. Fill in the **Name**, **Model**, **Type**, and **MAC Address** for the new NIC.

8. Click **Add** to save and attach the NIC to the virtual machine.

8.18.2.4.2. Networking fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name for the network interface controller.</td>
</tr>
<tr>
<td>Model</td>
<td>Indicates the model of the network interface controller. Supported values are e1000e and virtio.</td>
</tr>
<tr>
<td>Network</td>
<td>List of available network attachment definitions.</td>
</tr>
</tbody>
</table>
List of available binding methods. For the default pod network, **masquerade** is the only recommended binding method. For secondary networks, use the **bridge** binding method. The **masquerade** method is not supported for non-default networks. Select **SR-IOV** if you configured an SR-IOV network device and defined that network in the namespace.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>List of available binding methods. For the default pod network, <strong>masquerade</strong> is the only recommended binding method. For secondary networks, use the <strong>bridge</strong> binding method. The <strong>masquerade</strong> method is not supported for non-default networks. Select <strong>SR-IOV</strong> if you configured an SR-IOV network device and defined that network in the namespace.</td>
</tr>
<tr>
<td>MAC Address</td>
<td>MAC address for the network interface controller. If a MAC address is not specified, one is assigned automatically.</td>
</tr>
</tbody>
</table>

### 8.18.2.4.3. Attaching a virtual machine to a secondary network in the CLI

Attach a virtual machine to a secondary network by adding a bridge interface and specifying a network attachment definition in the virtual machine configuration.

This procedure uses a YAML file to demonstrate editing the configuration and applying the updated file to the cluster. You can alternatively use the `oc edit <object> <name>` command to edit an existing virtual machine.

**Prerequisites**

- Shut down the virtual machine before editing the configuration. If you edit a running virtual machine, you must restart the virtual machine for the changes to take effect.

**Procedure**

1. Create or edit a virtual machine configuration that you want to connect to the bridge network. Add the bridge interface to the `spec.template.spec.domain.devices.interfaces` list and the network attachment definition to the `spec.template.spec.networks` list. The name of the `interfaces` entry must be the same as the `networks` entry. The following example adds a bridge interface called `bridge-net` that connects to the `a-bridge-network` network attachment definition:

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  name: example-vm
spec:
  template:
    spec:
      domain:
        devices:
          interfaces:
            - masquerade: {}
              name: default
            - bridge: {}
```
name: bridge-net ①

... networks:
  - name: default
    pod: {}
  - name: bridge-net ②
    multus:
      networkName: <network-namespace>/<a-bridge-network> ③

1. The name of the bridge interface.
2. The name of the network. This value must match the `name` value of the corresponding `spec.template.spec.domain.devices.interfaces` entry.
3. The name of the network attachment definition, prefixed by the namespace where it exists. The namespace must be either the `default` namespace or the same namespace where the VM is to be created.

2. Apply the configuration:

   $ oc apply -f <example-vm.yaml>

3. Optional: If you edited a running virtual machine, you must restart it for the changes to take effect.

8.18.2.5. Additional resources

- Configuring IP addresses for virtual machines
- Configuring PXE booting for virtual machines
- Attaching a virtual machine to an SR-IOV network

8.18.3. Configuring IP addresses for virtual machines

You can configure either dynamically or statically provisioned IP addresses for virtual machines.

Prerequisites

- The virtual machine can connect to a secondary network
- To configure a dynamic IP for the virtual machine, you must have a DHCP server available on the secondary network.

8.18.3.1. Configuring an IP address for a new virtual machine using cloud-init

You can use cloud-init to configure an IP address when you create a virtual machine. The IP address can be dynamically or statically provisioned.

Procedure
Create a virtual machine configuration and include the cloud-init network details in the `spec.volumes.cloudInitNoCloud.networkData` field of the virtual machine configuration:

a. To configure a dynamic IP, specify the interface name and the `dhcp4` boolean:

```
kind: VirtualMachine
spec: ...
volumes:
- cloudInitNoCloud:
  networkData:
    version: 2
    ethernets:
      eth1:
        dhcp4: true
```

1. The interface name.
2. Uses DHCP to provision an IPv4 address.

b. To configure a static IP, specify the interface name and the IP address:

```
kind: VirtualMachine
spec: ...
volumes:
- cloudInitNoCloud:
  networkData:
    version: 2
    ethernets:
      eth1:
        addresses:
        - 10.10.10.14/24
```

1. The interface name.
2. The static IP address for the virtual machine.

### 8.18.4. Configuring an SR-IOV network device for virtual machines

You can configure a Single Root I/O Virtualization (SR-IOV) device for virtual machines in your cluster. This process is similar but not identical to configuring an SR-IOV device for OpenShift Container Platform.

#### 8.18.4.1. Prerequisites

- You must have installed the SR-IOV Operator.
- You must have configured the SR-IOV Operator.
- You must have enabled global SR-IOV and VT-d settings in the BIOS for the host.

#### 8.18.4.2. Automated discovery of SR-IOV network devices
The SR-IOV Network Operator searches your cluster for SR-IOV capable network devices on worker nodes. The Operator creates and updates a SriovNetworkNodeState custom resource (CR) for each worker node that provides a compatible SR-IOV network device.

The CR is assigned the same name as the worker node. The `status.interfaces` list provides information about the network devices on a node.

**IMPORTANT**

Do not modify a `SriovNetworkNodeState` object. The Operator creates and manages these resources automatically.

### 8.18.4.2.1. Example SriovNetworkNodeState object

The following YAML is an example of a `SriovNetworkNodeState` object created by the SR-IOV Network Operator:

**An SriovNetworkNodeState object**

```yaml
apiVersion: sriovnetwork.openshift.io/v1
kind: SriovNetworkNodeState
metadata:
  name: node-25
  namespace: openshift-sriov-network-operator
ownerReferences:
  - apiVersion: sriovnetwork.openshift.io/v1
    blockOwnerDeletion: true
    controller: true
    kind: SriovNetworkNodePolicy
    name: default
spec:
dpConfigVersion: "39824"
status:
  interfaces:
    - deviceID: "1017"
      driver: mlx5_core
      mtu: 1500
      name: ens785f0
      pciAddress: "0000:18:00.0"
      totalvfs: 8
      vendor: 15b3
    - deviceID: "1017"
      driver: mlx5_core
      mtu: 1500
      name: ens785f1
      pciAddress: "0000:18:00.1"
      totalvfs: 8
      vendor: 15b3
    - deviceID: 158b
      driver: i40e
      mtu: 1500
      name: ens817f0
      pciAddress: 0000:81:00.0
      totalvfs: 64
      vendor: "8086"
```
The value of the **name** field is the same as the name of the worker node.

The **interfaces** stanza includes a list of all of the SR-IOV devices discovered by the Operator on the worker node.

8.18.4.3. Configuring SR-IOV network devices


**NOTE**

When applying the configuration specified in a `SriovNetworkNodePolicy` object, the SR-IOV Operator might drain the nodes, and in some cases, reboot nodes.

It might take several minutes for a configuration change to apply.

**Prerequisites**

- You installed the OpenShift CLI (`oc`).
- You have access to the cluster as a user with the `cluster-admin` role.
- You have installed the SR-IOV Network Operator.
- You have enough available nodes in your cluster to handle the evicted workload from drained nodes.
- You have not selected any control plane nodes for SR-IOV network device configuration.

**Procedure**

1. Create an `SriovNetworkNodePolicy` object, and then save the YAML in the `<name>-sriov-node-network.yaml` file. Replace `<name>` with the name for this configuration.

```yaml
apiVersion: sriovnetwork.openshift.io/v1
kind: SriovNetworkNodePolicy
```

```yaml
- deviceID: 158b
driver: i40e
mtu: 1500
name: ens817f1
pciAddress: 0000:81:00.1
totalvfs: 64
vendor: "8086"
- deviceID: 158b
driver: i40e
mtu: 1500
name: ens803f0
pciAddress: 0000:86:00.0
totalvfs: 64
vendor: "8086"
syncStatus: Succeeded
```
Specify a name for the CR object.

Specify the namespace where the SR-IOV Operator is installed.

Specify the resource name of the SR-IOV device plug-in. You can create multiple `SriovNetworkNodePolicy` objects for a resource name.

Specify the node selector to select which nodes are configured. Only SR-IOV network devices on selected nodes are configured. The SR-IOV Container Network Interface (CNI) plug-in and device plug-in are deployed only on selected nodes.

Optional: Specify an integer value between 0 and 99. A smaller number gets higher priority, so a priority of 10 is higher than a priority of 99. The default value is 99.

Optional: Specify a value for the maximum transmission unit (MTU) of the virtual function. The maximum MTU value can vary for different NIC models.

Specify the number of the virtual functions (VF) to create for the SR-IOV physical network device. For an Intel network interface controller (NIC), the number of VFs cannot be larger than the total VFs supported by the device. For a Mellanox NIC, the number of VFs cannot be larger than 128.

The `nicSelector` mapping selects the Ethernet device for the Operator to configure. You do not need to specify values for all the parameters. It is recommended to identify the Ethernet adapter with enough precision to minimize the possibility of selecting an Ethernet device unintentionally. If you specify `rootDevices`, you must also specify a value for `vendor`, `deviceId`, or `pfNames`. If you specify both `pfNames` and `rootDevices` at the same time, ensure that they point to an identical device.

Optional: Specify the vendor hex code of the SR-IOV network device. The only allowed values are either 8086 or 15b3.

Optional: Specify the device hex code of SR-IOV network device. The only allowed values are 158b, 1015, 1017.

Optional: The parameter accepts an array of one or more physical function (PF) names for the Ethernet device.
The parameter accepts an array of one or more PCI bus addresses for the physical function of the Ethernet device. Provide the address in the following format: **0000:02:00.1**.

The **vfio-pci** driver type is required for virtual functions in OpenShift Virtualization.

Optional: Specify whether to enable remote direct memory access (RDMA) mode. For a Mellanox card, set `isRdma` to `false`. The default value is `false`.

NOTE

If `isRDMA` flag is set to **true**, you can continue to use the RDMA enabled VF as a normal network device. A device can be used in either mode.

1. Optional: Label the SR-IOV capable cluster nodes with `SriovNetworkNodePolicy.Spec.NodeSelector` if they are not already labeled. For more information about labeling nodes, see “Understanding how to update labels on nodes”.

2. Create the **SriovNetworkNodePolicy** object:

   ```bash
   $ oc create -f <name>-sriov-node-network.yaml
   ```

   Where `<name>` specifies the name for this configuration.

   After applying the configuration update, all the pods in `sriov-network-operator` namespace transition to the **Running** status.

3. To verify that the SR-IOV network device is configured, enter the following command. Replace `<node_name>` with the name of a node with the SR-IOV network device that you just configured.

   ```bash
   $ oc get sriovnetworknodes -n openshift-sriov-network-operator <node_name> -o jsonpath='{.status.syncStatus}'
   ```

**8.18.4.4. Next steps**

- Configuring an SR-IOV network attachment for virtual machines

**8.18.5. Connecting virtual machines to a service mesh**

OpenShift Virtualization is now integrated with OpenShift Service Mesh. You can monitor, visualize, and control traffic between pods that run virtual machine workloads on the default pod network with IPv4.

**8.18.5.1. Prerequisites**

- You must have installed the Service Mesh Operator and deployed the service mesh control plane.

- You must have added the namespace where the virtual machine is created to the service mesh member roll.

- You must use the **masquerade** binding method for the default pod network.

**8.18.5.2. Configuring a virtual machine for the service mesh**
To add a virtual machine (VM) workload to a service mesh, enable automatic sidecar injection in the VM configuration file by setting the `sidecar.istio.io/inject` annotation to `true`. Then expose your VM as a service to view your application in the mesh.

**Prerequisites**

- To avoid port conflicts, do not use ports used by the Istio sidecar proxy. These include ports 15000, 15001, 15006, 15008, 15020, 15021, and 15090.

**Procedure**

1. Edit the VM configuration file to add the `sidecar.istio.io/inject: "true"` annotation.

**Example configuration file**

```yaml
apiVersion: kubevirt.io/v1
kind: VirtualMachine
metadata:
  labels:
    kubevirt.io/vm: vm-istio
name: vm-istio
spec:
  runStrategy: Always
  template:
    metadata:
      labels:
        kubevirt.io/vm: vm-istio
      app: vm-istio
    annotations:
      sidecar.istio.io/inject: "true"
    spec:
      domain:
        devices:
          interfaces:
            - name: default
              masquerade: {}
          disks:
            - disk:
                bus: virtio
                name: containerdisk
            - disk:
                bus: virtio
                name: cloudinitdisk
      resources:
        requests:
          memory: 1024M
      networks:
        - name: default
          pod: {}
      terminationGracePeriodSeconds: 180
      volumes:
        - containerDisk:
            image: registry:5000/kubevirt/fedora-cloud-container-disk-demo:devel
            name: containerdisk
```
1. The key/value pair (label) that must be matched to the service selector attribute.
2. The annotation to enable automatic sidecar injection.
3. The binding method (masquerade mode) for use with the default pod network.

2. Apply the VM configuration:

   $ oc apply -f <vm_name>.yaml

   The name of the virtual machine YAML file.

3. Create a **Service** object to expose your VM to the service mesh.

   ```yaml
   apiVersion: v1
   kind: Service
   metadata:
     name: vm-istio
   spec:
     selector:
       app: vm-istio
     ports:
       - port: 8080
         name: http
         protocol: TCP
   ```

   The service selector that determines the set of pods targeted by a service. This attribute corresponds to the `spec.metadata.labels` field in the VM configuration file. In the above example, the **Service** object named *vm-istio* targets TCP port 8080 on any pod with the label `app=vm-istio`.

4. Create the service:

   $ oc create -f <service_name>.yaml

   The name of the service YAML file.

---

### 8.18.6. Defining an SR-IOV network

You can create a network attachment for a Single Root I/O Virtualization (SR-IOV) device for virtual machines.

After the network is defined, you can attach virtual machines to the SR-IOV network.

#### 8.18.6.1. Prerequisites

- You must have configured an SR-IOV device for virtual machines.

#### 8.18.6.2. Configuring SR-IOV additional network
You can configure an additional network that uses SR-IOV hardware by creating a **SriovNetwork** object. When you create a **SriovNetwork** object, the SR-IOV Operator automatically creates a **NetworkAttachmentDefinition** object.

Users can then attach virtual machines to the SR-IOV network by specifying the network in the virtual machine configurations.

**NOTE**

Do not modify or delete a **SriovNetwork** object if it is attached to any pods or virtual machines in the **running** state.

**Prerequisites**

- Install the OpenShift CLI (**oc**).
- Log in as a user with **cluster-admin** privileges.

**Procedure**

1. Create the following **SriovNetwork** object, and then save the YAML in the `<name>-sriov-network.yaml` file. Replace `<name>` with a name for this additional network.

```
apiVersion: sriovnetwork.openshift.io/v1
kind: SriovNetwork
metadata:
  name: `<name>`
  namespace: openshift-sriov-network-operator
spec:
  resourceName: `<sriov_resource_name>`
  networkNamespace: `<target_namespace>`
  vlan: `<vlan>`
  spoofChk: "<spoof_check>"
  linkState: `<link_state>`
  maxTxRate: `<max_tx_rate>`
  minTxRate: `<min_rx_rate>`
  vlanQoS: `<vlan_qos>`
  trust: "<trust_vf>"
  capabilities: `<capabilities>`
```

1. Replace `<name>` with a name for the object. The SR-IOV Network Operator creates a **NetworkAttachmentDefinition** object with same name.
2. Specify the namespace where the SR-IOV Network Operator is installed.
3. Replace `<sriov_resource_name>` with the value for the .spec.resourceName parameter from the **SrivovNetworkNodePolicy** object that defines the SR-IOV hardware for this additional network.
4. Replace `<target_namespace>` with the target namespace for the SriovNetwork. Only pods or virtual machines in the target namespace can attach to the SriovNetwork.
5. Optional: Replace `<vlan>` with a Virtual LAN (VLAN) ID for the additional network. The integer value must be from 0 to 4095. The default value is 0.
6. Optional: Replace `<spoof_check>` with the spoof check mode of the VF. The allowed values are the strings "on" and "off".

**IMPORTANT**

You must enclose the value you specify in quotes or the CR is rejected by the SR-IOV Network Operator.

7. Optional: Replace `<link_state>` with the link state of virtual function (VF). Allowed value are `enable`, `disable` and `auto`.

8. Optional: Replace `<max_tx_rate>` with a maximum transmission rate, in Mbps, for the VF.

9. Optional: Replace `<min_tx_rate>` with a minimum transmission rate, in Mbps, for the VF. This value should always be less than or equal to Maximum transmission rate.

**NOTE**

Intel NICs do not support the `minTxRate` parameter. For more information, see BZ#1772847.

10. Optional: Replace `<vlan_qos>` with an IEEE 802.1p priority level for the VF. The default value is `0`.

11. Optional: Replace `<trust_vf>` with the trust mode of the VF. The allowed values are the strings "on" and "off".

**IMPORTANT**

You must enclose the value you specify in quotes or the CR is rejected by the SR-IOV Network Operator.

12. Optional: Replace `<capabilities>` with the capabilities to configure for this network.

2. To create the object, enter the following command. Replace `<name>` with a name for this additional network.

   ```bash
   $ oc create -f <name>-sriov-network.yaml
   ```

3. Optional: To confirm that the `NetworkAttachmentDefinition` object associated with the `SrivovNetwork` object that you created in the previous step exists, enter the following command. Replace `<namespace>` with the namespace you specified in the `SrivovNetwork` object.

   ```bash
   $ oc get net-attach-def -n <namespace>
   ```

**8.18.6.3. Next steps**

- Attaching a virtual machine to an SR-IOV network.

**8.18.7. Attaching a virtual machine to an SR-IOV network**

You can attach a virtual machine to use a Single Root I/O Virtualization (SR-IOV) network as a secondary network.
8.18.7.1. Prerequisites

- You must have configured an SR-IOV device for virtual machines.
- You must have defined an SR-IOV network.

8.18.7.2. Attaching a virtual machine to an SR-IOV network

You can attach the virtual machine to the SR-IOV network by including the network details in the virtual machine configuration.

Procedure

1. Include the SR-IOV network details in the `spec.domain.devices.interfaces` and `spec.networks` of the virtual machine configuration:

```yaml
kind: VirtualMachine
...
spec:
  domain:
    devices:
      interfaces:
      - name: <default> 1
        masquerade: {} 2
      - name: <nic1> 3
        sriov: {}
    networks:
      - name: <default> 4
        pod: {}
      - name: <nic1> 5
        multus:
          networkName: <sriov-network> 6
 ...
```

1. A unique name for the interface that is connected to the pod network.
2. The `masquerade` binding to the default pod network.
3. A unique name for the SR-IOV interface.
4. The name of the pod network interface. This must be the same as the `interfaces.name` that you defined earlier.
5. The name of the SR-IOV interface. This must be the same as the `interfaces.name` that you defined earlier.
6. The name of the SR-IOV network attachment definition.

2. Apply the virtual machine configuration:

```bash
$ oc apply -f <vm-sriov.yaml> 1
```

1. The name of the virtual machine YAML file.
8.18.8. Viewing the IP address of NICs on a virtual machine

You can view the IP address for a network interface controller (NIC) by using the web console or the oc client. The QEMU guest agent displays additional information about the virtual machine’s secondary networks.

8.18.8.1. Prerequisites

- Install the QEMU guest agent on the virtual machine.

8.18.8.2. Viewing the IP address of a virtual machine interface in the CLI

The network interface configuration is included in the `oc describe vmi <vmi_name>` command.

You can also view the IP address information by running `ip addr` on the virtual machine, or by running `oc get vmi <vmi_name> -o yaml`.

Procedure

- Use the `oc describe` command to display the virtual machine interface configuration:

  ```
  $ oc describe vmi <vmi_name>
  ```

Example output

```
... Interfaces:   Interface Name:  eth0
  Ip Address:   10.244.0.37/24
  Ip Addresses: 10.244.0.37/24
  fe80::858:aff:fef4:25/64
  Mac: 0a:58:0a:f4:00:25
  Name: default
  Interface Name: v2
  Ip Address:  1.1.1.7/24
  Ip Addresses:
  1.1.1.7/24
  fe80::f4d9:70ff:fe13:9089/64
  Interface Name: v1
  Ip Address:  1.1.1.1/24
  Ip Addresses:
  1.1.1.1/24
  1.1.1.2/24
  1.1.1.4/24
  2001:de7:0:f101::1/64
  2001:db8:0:f101::1/64
  fe80::1420:84ff:fe10:17aa/64
  Mac: 16:20:84:10:17:aa
```

8.18.8.3. Viewing the IP address of a virtual machine interface in the web console

The IP information displays in the Virtual Machine Overview screen for the virtual machine.
Procedure

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine name to open the Virtual Machine Overview screen.

The information for each attached NIC is displayed under IP Address.

8.18.9. Using a MAC address pool for virtual machines

The KubeMacPool component provides a MAC address pool service for virtual machine NICs in a namespace.

8.18.9.1. About KubeMacPool

KubeMacPool provides a MAC address pool per namespace and allocates MAC addresses for virtual machine NICs from the pool. This ensures that the NIC is assigned a unique MAC address that does not conflict with the MAC address of another virtual machine.

Virtual machine instances created from that virtual machine retain the assigned MAC address across reboots.

NOTE

KubeMacPool does not handle virtual machine instances created independently from a virtual machine.

KubeMacPool is enabled by default when you install OpenShift Virtualization. You can disable a MAC address pool for a namespace by adding the mutatevirtualmachines.kubemacpool.io=ignore label to the namespace. Re-enable KubeMacPool for the namespace by removing the label.

8.18.9.2. Disabling a MAC address pool for a namespace in the CLI

Disable a MAC address pool for virtual machines in a namespace by adding the mutatevirtualmachines.kubemacpool.io=ignore label to the namespace.

Procedure

- Add the mutatevirtualmachines.kubemacpool.io=ignore label to the namespace. The following example disables KubeMacPool for two namespaces, <namespace1> and <namespace2>:

  $ oc label namespace <namespace1> <namespace2> mutatevirtualmachines.kubemacpool.io=ignore

8.18.9.3. Re-enabling a MAC address pool for a namespace in the CLI

If you disabled KubeMacPool for a namespace and want to re-enable it, remove the mutatevirtualmachines.kubemacpool.io=ignore label from the namespace.
NOTE

Earlier versions of OpenShift Virtualization used the label `mutatevirtualmachines.kubemacpool.io=allocate` to enable KubeMacPool for a namespace. This is still supported but redundant as KubeMacPool is now enabled by default.

Procedure

- Remove the KubeMacPool label from the namespace. The following example re-enables KubeMacPool for two namespaces, `<namespace1>` and `<namespace2>`:

  ```
  $ oc label namespace <namespace1> <namespace2>
  mutatevirtualmachines.kubemacpool.io-
  ```

8.19. VIRTUAL MACHINE DISKS

8.19.1. Storage features

Use the following table to determine feature availability for local and shared persistent storage in OpenShift Virtualization.

8.19.1.1. OpenShift Virtualization storage feature matrix

Table 8.6. OpenShift Virtualization storage feature matrix

<table>
<thead>
<tr>
<th></th>
<th>Virtual machine live migration</th>
<th>Host-assisted virtual machine disk cloning</th>
<th>Storage-assisted virtual machine disk cloning</th>
<th>Virtual machine snapshots</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenShift Data Foundation: RBD block-mode volumes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>OpenShift Virtualization hostpath provisioner</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Other single-node writable storage</td>
<td>No</td>
<td>Yes</td>
<td>Yes [2]</td>
<td>Yes [2]</td>
</tr>
</tbody>
</table>

1. PVCs must request a ReadWriteMany access mode.

2. Storage provider must support both Kubernetes and CSI snapshot APIs
NOTE
You cannot live migrate virtual machines that use:

- A storage class with ReadWriteOnce (RWO) access mode
- Passthrough features such as GPUs

Do not set the evictionStrategy field to LiveMigrate for these virtual machines.

8.19.2. Configuring local storage for virtual machines

Configure storage for your virtual machines. When configuring local storage, use the hostpath provisioner (HPP).

8.19.2.1. About the hostpath provisioner (HPP)

When you install the OpenShift Virtualization Operator, the Hostpath Provisioner Operator is automatically installed. The HPP is a local storage provisioner designed for OpenShift Virtualization that is created by the Hostpath Provisioner Operator. To use the HPP, you must create a HPP custom resource.

IMPORTANT

In OpenShift Virtualization 4.10, the HPP Operator configures the Kubernetes CSI driver. The Operator also recognizes the existing (legacy) format of the custom resource.

The legacy HPP and the CSI host path driver are supported in parallel for a number of releases. However, at some point, the legacy HPP will no longer be supported. If you use the HPP, plan to create a storage class for the CSI driver as part of your migration strategy.

If you upgrade to OpenShift Virtualization version 4.10 on an existing cluster, the HPP Operator is upgraded and the system performs the following actions:

- The CSI driver is installed.
- The CSI driver is configured with the contents of your legacy custom resource.

If you install OpenShift Virtualization version 4.10 on a new cluster, you must perform the following actions:

- Create the HPP custom resource including a storagePools stanza in the HPP custom resource.
- Create a storage class for the CSI driver.

8.19.2.2. Create the HPP custom resource with a storage pool

Storage pools allow you to specify the name and path that are used by the CSI driver.

Procedure

1. Create a YAML file for the HPP custom resource with a storagePools stanza in the YAML. For example:
2. Edit the file. For example:

```yaml
apiVersion: hostpathprovisioner.kubevirt.io.v1beta1
kind: HostPathProvisioner
metadata:
  name: hostpath-provisioner
spec:
  imagePullPolicy: IfNotPresent
  storagePools:
    - name: <any_name>
      path: "</var/myvolumes>"
  workload:
    nodeSelector:
      kubernetes.io/os: linux
```

1. The `storagePools` stanza is an array to which you can add multiple entries.
2. Create directories under this node path. Read/write access is required. Ensure that the node-level directory (`/var/myvolumes`) is not on the same partition as the operating system. If it is on the same partition as the operating system, users can potentially fill the operating system partition and impact performance or cause the node to become unstable or unusable.

3. Save the file and exit.

### 8.19.2.3. Creating a storage class

When you create a storage class, you set parameters that affect the dynamic provisioning of persistent volumes (PVs) that belong to that storage class.

In order to use the host path provisioner (HPP) you must create an associated storage class for the CSI driver with the `storagePools` stanza.

**NOTE**

You cannot update a `StorageClass` object’s parameters after you create it.

**NOTE**

Virtual machines use data volumes that are based on local PVs. Local PVs are bound to specific nodes. While the disk image is prepared for consumption by the virtual machine, it is possible that the virtual machine cannot be scheduled to the node where the local storage PV was previously pinned.

To solve this problem, use the Kubernetes pod scheduler to bind the PVC to a PV on the correct node. By using the `StorageClass` value with `volumeBindingMode` parameter set to `WaitForFirstConsumer`, the binding and provisioning of the PV is delayed until a pod is created using the PVC.

### 8.19.2.3.1. Creating a storage class for the CSI driver with the `storagePools` stanza
Use this procedure to create a storage class for use with the HPP CSI driver implementation. You must create this storage class to use HPP in OpenShift Virtualization 4.10 and later.

Procedure

1. Create a YAML file for defining the storage class. For example:

   ```sh
touch <storageclass_csi>.yaml
   ```

2. Edit the file. For example:

   ```yaml
   apiVersion: storage.k8s.io/v1
   kind: StorageClass
   metadata:
     name: hostpath-csi
   provisioner: kubevirt.io.hostpath-provisioner
   reclaimPolicy: Delete
   volumeBindingMode: WaitForFirstConsumer
   parameters:
     storagePool: <any_name>
   ```

   1. Assign any meaningful name to the storage class. In this example, `csi` is used to specify that the class is using the CSI provisioner instead of the legacy provisioner. Choosing descriptive names for storage classes, based on legacy or CSI driver provisioning, eases implementation of your migration strategy.

   2. The legacy provisioner uses `kubevirt.io/hostpath-provisioner`. The CSI driver uses `kubevirt.io.hostpath-provisioner`.

   3. The two possible `reclaimPolicy` values are `Delete` and `Retain`. If you do not specify a value, the storage class defaults to `Delete`.

   4. The `volumeBindingMode` parameter determines when dynamic provisioning and volume binding occur. Specify `WaitForFirstConsumer` to delay the binding and provisioning of a PV until after a pod that uses the persistent volume claim (PVC) is created. This ensures that the PV meets the pod’s scheduling requirements.

   5. `<any_name>` must match the name of the storage pool, which you define in the HPP custom resource.

3. Save the file and exit.

4. Create the `StorageClass` object:

   ```sh
   oc create -f <storageclass_csi>.yaml
   ```

8.19.2.3.2. Creating a storage class for the legacy hostpath provisioner

Use this procedure to create a storage class for the legacy hostpath provisioner (HPP). You do not need to explicitly add a `storagePool` parameter.

Procedure
1. Create a YAML file for defining the storage class. For example:

   $ touch storageclass.yaml

2. Edit the file. For example:

   ```yaml
   apiVersion: storage.k8s.io/v1
   kind: StorageClass
   metadata:
     name: hostpath-provisioner
   provisioner: kubevirt.io/hostpath-provisioner
   reclaimPolicy: Delete
   volumeBindingMode: WaitForFirstConsumer
   ```

   1. Assign any meaningful name to the storage class. In this example, `csi` is used to specify that the class is using the CSI provisioner, instead of the legacy provisioner. Choosing descriptive names for storage classes, based on legacy or CSI driver provisioning, eases implementation of your migration strategy.

   2. The two possible `reclaimPolicy` values are `Delete` and `Retain`. If you do not specify a value, the storage class defaults to `Delete`.

   3. The `volumeBindingMode` value determines when dynamic provisioning and volume binding occur. Specify the `WaitForFirstConsumer` value to delay the binding and provisioning of a PV until after a pod that uses the persistent volume claim (PVC) is created. This ensures that the PV meets the pod’s scheduling requirements.

3. Save the file and exit.

4. Create the `StorageClass` object:

   $ oc create -f storageclass.yaml

**Additional resources**

- [Storage classes](#)

In addition to configuring a basic storage pool for use with the HPP, you have the option of creating single storage pools with the `pvcTemplate` specification as well as multiple storage pools.

### 8.19.2.4. Creating a storage pool using a `pvcTemplate` specification in a host path provisioner (HPP) custom resource.

If you have a single large persistent volume (PV) on your node, you might want to virtually divide the volume and use one partition to store only the HPP volumes. By defining a storage pool using a `pvcTemplate` specification in the HPP custom resource, you can virtually split the PV into multiple smaller volumes, providing more flexibility in data allocation.

The `pvcTemplate` matches the `spec` portion of a persistent volume claim (PVC). For example:

```yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
```
A **pvcTemplate** is the spec (specification) section of a PVC

The Operator creates a PVC from the PVC template for each node containing the HPP CSI driver. The PVC created from the PVC template consumes the single large PV, allowing the HPP to create smaller dynamic volumes.

You can create any combination of storage pools. You can combine standard storage pools with storage pools that use PVC templates in the **storagePools** stanza.

**Procedure**

1. Create a YAML file for the CSI custom resource specifying a single **pvcTemplate** storage pool. For example:

   ```yaml
   $ touch hostpathprovisioner_cr_pvc.yaml
   ```

2. Edit the file. For example:

   ```yaml
   apiVersion: hostpathprovisioner.kubevirt.io/v1beta1
   kind: HostPathProvisioner
   metadata:
     name: hostpath-provisioner
   spec:
     imagePullPolicy: IfNotPresent
     storagePools:
     - name: <any_name>  
       path: " </var/myvolumes>
       pvcTemplate:
         volumeMode: Block  
         storageClassName: <any_storage_class>
         accessModes:
           - ReadWriteOnce
         resources:
           requests:
             storage: 5Gi
   workload:
     nodeSelector:
       kubernetes.io/os: linux
   ```
3. Save the file and exit.

Additional resources

- Customizing the storage profile

8.19.3. Creating data volumes

When you create a data volume, the Containerized Data Importer (CDI) creates a persistent volume claim (PVC) and populates the PVC with your data. You can create a data volume as either a standalone resource or by using a `dataVolumeTemplate` resource in a virtual machine specification. You create a data volume by using either the PVC API or storage APIs.

**IMPORTANT**

When using OpenShift Virtualization with OpenShift Container Platform Container Storage, specify RBD block mode persistent volume claims (PVCs) when creating virtual machine disks. With virtual machine disks, RBD block mode volumes are more efficient and provide better performance than Ceph FS or RBD filesystem-mode PVCs.

To specify RBD block mode PVCs, use the 'ocs-storagecluster-ceph-rbd' storage class and `VolumeMode: Block`.

**TIP**

Whenever possible, use the storage API to optimize space allocation and maximize performance.

A storage profile is a custom resource that the CDI manages. It provides recommended storage settings based on the associated storage class. A storage profile is allocated for each storage class.

Storage profiles enable you to create data volumes quickly while reducing coding and minimizing potential errors.
For recognized storage types, the CDI provides values that optimize the creation of PVCs. However, you can configure automatic settings for a storage class if you customize the storage profile.

### 8.19.3.1. Creating data volumes using the storage API

When you create a data volume using the storage API, the Containerized Data Interface (CDI) optimizes your persistent volume claim (PVC) allocation based on the type of storage supported by your selected storage class. You only have to specify the data volume name, namespace, and the amount of storage that you want to allocate.

For example:

- When using Ceph RBD, `accessModes` is automatically set to **ReadWriteMany**, which enables live migration. `volumeMode` is set to **Block** to maximize performance.

- When you are using `volumeMode: Filesystem`, more space will automatically be requested by the CDI, if required to accommodate file system overhead.

In the following YAML, using the storage API requests a data volume with two gigabytes of usable space. The user does not need to know the `volumeMode` in order to correctly estimate the required persistent volume claim (PVC) size. The CDI chooses the optimal combination of `accessModes` and `volumeMode` attributes automatically. These optimal values are based on the type of storage or the defaults that you define in your storage profile. If you want to provide custom values, they override the system-calculated values.

**Example DataVolume definition**

```yaml
datavolume: ... # 1
name: ... # 1
namespace: ... # 1
name: ... # 1
storageclass: ... # 1
storage: ... # 1
resources: ... # 1
requests: ... # 1
storageclass: ... # 1
```

1. **The name of the new data volume.**
2. **Indicate that the source of the import is an existing persistent volume claim (PVC).**
3. **The namespace where the source PVC exists.**
4. **The name of the source PVC.**
5. **Indicates allocation using the storage API.**
6. **Specifies the amount of available space that you request for the PVC.**
7. **Optional: The name of the storage class. If the storage class is not specified, the system default storage class is used.**
8.19.3.2. Creating data volumes using the PVC API

When you create a data volume using the PVC API, the Containerized Data Interface (CDI) creates the data volume based on what you specify for the following fields:

- **accessModes** (*ReadWriteOnce, ReadWriteMany, or ReadOnlyMany*)
- **volumeMode** (*Filesystem* or *Block*)
- **capacity** of storage (*5Gi*, for example)

In the following YAML, using the PVC API allocates a data volume with a storage capacity of two gigabytes. You specify an access mode of *ReadWriteMany* to enable live migration. Because you know the values your system can support, you specify *Block* storage instead of the default, *Filesystem*.

Example DataVolume definition

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: <datavolume>  
spec:
  source:
    pvc:
      namespace: "<source_namespace>"  
      name: "<my_vm_disk>"
    pvc:
      accessModes:  
        - ReadWriteMany
      resources:
        storage: 2Gi
      volumeMode: Block
      storageClassName: <storage_class>
```

1. The name of the new data volume.
2. In the **source** section, **pvc** indicates that the source of the import is an existing persistent volume claim (PVC).
3. The namespace where the source PVC exists.
4. The name of the source PVC.
5. Indicates allocation using the PVC API.
6. **accessModes** is required when using the PVC API.
7. Specifies the amount of space you are requesting for your data volume.
8. Specifies that the destination is a block PVC.
Optionally, specify the storage class. If the storage class is not specified, the system default storage class is used.

**IMPORTANT**

When you explicitly allocate a data volume by using the PVC API and you are not using `volumeMode: Block`, consider file system overhead.

File system overhead is the amount of space required by the file system to maintain its metadata. The amount of space required for file system metadata is file system dependent. Failing to account for file system overhead in your storage capacity request can result in an underlying persistent volume claim (PVC) that is not large enough to accommodate your virtual machine disk.

If you use the storage API, the CDI will factor in file system overhead and request a larger persistent volume claim (PVC) to ensure that your allocation request is successful.

### 8.19.3.3. Customizing the storage profile

You can specify default parameters by editing the `StorageProfile` object for the provisioner’s storage class. These default parameters only apply to the persistent volume claim (PVC) if they are not configured in the `DataVolume` object.

**Prerequisites**

- Ensure that your planned configuration is supported by the storage class and its provider. Specifying an incompatible configuration in a storage profile causes volume provisioning to fail.

**NOTE**

An empty **status** section in a storage profile indicates that a storage provisioner is not recognized by the Containerized Data Interface (CDI). Customizing a storage profile is necessary if you have a storage provisioner that is not recognized by the CDI. In this case, the administrator sets appropriate values in the storage profile to ensure successful allocations.

**WARNING**

If you create a data volume and omit YAML attributes and these attributes are not defined in the storage profile, then the requested storage will not be allocated and the underlying persistent volume claim (PVC) will not be created.

**Procedure**

1. Edit the storage profile. In this example, the provisioner is not recognized by CDI:

   ```
   $ oc edit -n openshift-cnv storageprofile <storage_class>
   ```

   **Example storage profile**
2. Provide the needed attribute values in the storage profile:

**Example storage profile**

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: StorageProfile
metadata:
  name: <unknown_provisioner_class>
spec: {}
status:
  provisioner: <unknown_provisioner>
  storageClass: <unknown_provisioner_class>
```

1. The `accessModes` that you select.
2. The `volumeMode` that you select.

After you save your changes, the selected values appear in the storage profile `status` element.

### 8.19.3.3.1. Setting a default cloning strategy using a storage profile

You can use storage profiles to set a default cloning method for a storage class, creating a cloning strategy. Setting cloning strategies can be helpful, for example, if your storage vendor only supports certain cloning methods. It also allows you to select a method that limits resource usage or maximizes performance.

Cloning strategies can be specified by setting the `cloneStrategy` attribute in a storage profile to one of these values:

- **snapshot** - This method is used by default when snapshots are configured. This cloning strategy uses a temporary volume snapshot to clone the volume. The storage provisioner must support CSI snapshots.

- **copy** - This method uses a source pod and a target pod to copy data from the source volume to the target volume. Host-assisted cloning is the least efficient method of cloning.

- **csi-clone** - This method uses the CSI clone API to efficiently clone an existing volume without using an interim volume snapshot. Unlike `snapshot` or `copy`, which are used by default if no
storage profile is defined, CSI volume cloning is only used when you specify it in the `StorageProfile` object for the provisioner’s storage class.

NOTE

You can also set clone strategies using the CLI without modifying the default `claimPropertySets` in your YAML `spec` section.

Example storage profile

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
class: StorageProfile
metadata:
  name: <provisioner_class>

spec:
  claimPropertySets:
  - accessModes:
    - ReadWriteOnce
  volumeMode:
    Filesystem
  cloneStrategy:
    csi-clone
  status:
    provisioner: <provisioner>
    storageClass: <provisioner_class>
```

1. The `accessModes` that you select.
2. The `volumeMode` that you select.
3. The default cloning method of your choice. In this example, CSI volume cloning is specified.

8.19.3.4. Additional resources

- Creating a storage class
- Overriding the default file system overhead value
- Cloning a data volume using smart cloning

8.19.4. Reserving PVC space for file system overhead

By default, the Containerized Data Importer (CDI) reserves space for file system overhead data in persistent volume claims (PVCs) that use the `Filesystem` volume mode. You can set the percentage that CDI reserves for this purpose globally and for specific storage classes.

8.19.4.1. How file system overhead affects space for virtual machine disks

When you add a virtual machine disk to a persistent volume claim (PVC) that uses the `Filesystem` volume mode, you must ensure that there is enough space on the PVC for:

- The virtual machine disk.
By default, CDI reserves 5.5% of the PVC space for overhead, reducing the space available for virtual machine disks by that amount.

If a different value works better for your use case, you can configure the overhead value by editing the CDI object. You can change the value globally and you can specify values for specific storage classes.

### 8.19.4.2. Overriding the default file system overhead value

Change the amount of persistent volume claim (PVC) space that the Containerized Data Importer (CDI) reserves for file system overhead by editing the `spec.config.filesystemOverhead` attribute of the CDI object.

**Prerequisites**

- Install the OpenShift CLI (`oc`).

**Procedure**

1. Open the CDI object for editing by running the following command:

   ```bash
   $ oc edit cdi
   ```

2. Edit the `spec.config.filesystemOverhead` fields, populating them with your chosen values:

   ```yaml
   ...  
   spec:  
     config:  
       filesystemOverhead:  
         global: "<new_global_value>"  
         storageClass:  
           <storage_class_name>: "<new_value_for_this_storage_class>"
   ```

   **1** The file system overhead percentage that CDI uses across the cluster. For example, `global: "0.07"` reserves 7% of the PVC for file system overhead.

   **2** The file system overhead percentage for the specified storage class. For example, `mystorageclass: "0.04"` changes the default overhead value for PVCs in the `mystorageclass` storage class to 4%.

3. Save and exit the editor to update the CDI object.

**Verification**

- View the CDI status and verify your changes by running the following command:

  ```bash
  $ oc get cdi -o yaml
  ```

### 8.19.5. Configuring CDI to work with namespaces that have a compute resource quota
You can use the Containerized Data Importer (CDI) to import, upload, and clone virtual machine disks into namespaces that are subject to CPU and memory resource restrictions.

8.19.5.1. About CPU and memory quotas in a namespace

A resource quota, defined by the ResourceQuota object, imposes restrictions on a namespace that limit the total amount of compute resources that can be consumed by resources within that namespace.

The HyperConverged custom resource (CR) defines the user configuration for the Containerized Data Importer (CDI). The CPU and memory request and limit values are set to a default value of 0. This ensures that pods created by CDI that do not specify compute resource requirements are given the default values and are allowed to run in a namespace that is restricted with a quota.

8.19.5.2. Overriding CPU and memory defaults

Modify the default settings for CPU and memory requests and limits for your use case by adding the spec.resourceRequirements.storageWorkloads stanza to the HyperConverged custom resource (CR).

Prerequisites

- Install the OpenShift CLI (oc).

Procedure

1. Edit the HyperConverged CR by running the following command:

   ```
   $ oc edit hco -n openshift-cnv kubevirt-hyperconverged
   ```

2. Add the spec.resourceRequirements.storageWorkloads stanza to the CR, setting the values based on your use case. For example:

   ```
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
   spec:
     resourceRequirements:
       storageWorkloads:
         limits:
           cpu: "500m"
           memory: "2Gi"
         requests:
           cpu: "250m"
           memory: "1Gi"
   ```

3. Save and exit the editor to update the HyperConverged CR.

8.19.5.3. Additional resources

- Resource quotas per project

8.19.6. Managing data volume annotations
Data volume (DV) annotations allow you to manage pod behavior. You can add one or more annotations to a data volume, which then propagates to the created importer pods.

### 8.19.6.1. Example: Data volume annotations

This example shows how you can configure data volume (DV) annotations to control which network the importer pod uses. The `v1.multus-cni.io/default-network: bridge-network` annotation causes the pod to use the multus network named `bridge-network` as its default network. If you want the importer pod to use both the default network from the cluster and the secondary multus network, use the `k8s.v1.cni.cncf.io/networks: <network_name>` annotation.

#### Multus network annotation example

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: dv-ann
  annotations:
    v1.multus-cni.io/default-network: bridge-network
spec:
  source:
    http:
      url: "example.exampleurl.com"
  pvc:
    accessModes: 
      - ReadWriteOnce
    resources:
      requests:
        storage: 1Gi
```

#### 8.19.7. Using preallocation for data volumes

The Containerized Data Importer can preallocate disk space to improve write performance when creating data volumes.

You can enable preallocation for specific data volumes.

#### 8.19.7.1. About preallocation

The Containerized Data Importer (CDI) can use the QEMU preallocate mode for data volumes to improve write performance. You can use preallocation mode for importing and uploading operations and when creating blank data volumes.

If preallocation is enabled, CDI uses the better preallocation method depending on the underlying file system and device type:

- **fallocate**
  - If the file system supports it, CDI uses the operating system's `fallocate` call to preallocate space by using the `posix_fallocate` function, which allocates blocks and marks them as uninitialized.

- **full**
If **fallocate** mode cannot be used, **full** mode allocates space for the image by writing data to the underlying storage. Depending on the storage location, all the empty allocated space might be zeroed.

### 8.19.7.2. Enabling preallocation for a data volume

You can enable preallocation for specific data volumes by including the `spec.preallocation` field in the data volume manifest. You can enable preallocation mode in either the web console or by using the OpenShift CLI (`oc`).

Preallocation mode is supported for all CDI source types.

**Procedure**

- Specify the `spec.preallocation` field in the data volume manifest:

  ```yaml
  apiVersion: cdi.kubevirt.io/v1beta1
  kind: DataVolume
  metadata:
    name: preallocated-datavolume
  spec:
    source:
      ...
    pvc:
      ...
    preallocation: true
  ```

1. All CDI source types support preallocation, however preallocation is ignored for cloning operations.
2. The `preallocation` field is a boolean that defaults to false.

### 8.19.8. Uploading local disk images by using the web console

You can upload a locally stored disk image file by using the web console.

#### 8.19.8.1. Prerequisites

- You must have a virtual machine image file in IMG, ISO, or QCOW2 format.
- If you require scratch space according to the CDI supported operations matrix, you must first define a storage class or prepare CDI scratch space for this operation to complete successfully.

#### 8.19.8.2. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.
<table>
<thead>
<tr>
<th>Content types</th>
<th>HTTP</th>
<th>HTTPS</th>
<th>HTTP basic auth</th>
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</tr>
</thead>
<tbody>
<tr>
<td>KubeVirt (QCOW2)</td>
<td>✓ QCOW2 ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2* ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2 ✓ GZ* ✓ XZ*</td>
<td>✓ QCOW2* ☐ GZ ☐ XZ</td>
<td>✓ QCOW2* ✓ GZ* ✓ XZ*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW ✓ GZ ✓ XZ</td>
<td>✓ RAW* ☐ GZ ☐ XZ</td>
<td>✓ RAW* ✓ GZ* ✓ XZ*</td>
</tr>
</tbody>
</table>

- ✓ Supported operation
- ☐ Unsupported operation
- * Requires scratch space
- ** Requires scratch space if a custom certificate authority is required

### 8.19.8.3. Uploading an image file using the web console

Use the web console to upload an image file to a new persistent volume claim (PVC). You can later use this PVC to attach the image to new virtual machines.

**Prerequisites**

- You must have one of the following:
  - A raw virtual machine image file in either ISO or IMG format.
  - A virtual machine image file in QCOW2 format.
- For best results, compress your image file according to the following guidelines before you upload it:
  - Compress a raw image file by using `xz` or `gzip`.

**NOTE**

Using a compressed raw image file results in the most efficient upload.

- Compress a QCOW2 image file by using the method that is recommended for your client:
  - If you use a Linux client, `sparsify` the QCOW2 file by using the `virt-sparsify` tool.
  - If you use a Windows client, compress the QCOW2 file by using `xz` or `gzip`.

**Procedure**

1. From the side menu of the web console, click **Storage → Persistent Volume Claims**
2. Click the **Create Persistent Volume Claim** drop-down list to expand it.
3. Click **With Data Upload Form** to open the **Upload Data to Persistent Volume Claim** page.
4. Click **Browse** to open the file manager and select the image that you want to upload, or drag the file into the **Drag a file here or browse to upload** field.

5. Optional: Set this image as the default image for a specific operating system.
   a. Select the **Attach this data to a virtual machine operating system** check box.
   b. Select an operating system from the list.

6. The **Persistent Volume Claim Name** field is automatically filled with a unique name and cannot be edited. Take note of the name assigned to the PVC so that you can identify it later, if necessary.

7. Select a storage class from the **Storage Class** list.

8. In the **Size** field, enter the size value for the PVC. Select the corresponding unit of measurement from the drop-down list.

   ![WARNING]
   The PVC size must be larger than the size of the uncompressed virtual disk.

9. Select an **Access Mode** that matches the storage class that you selected.

10. Click **Upload**.

### 8.19.8.4. Additional resources

- **Configure preallocation mode** to improve write performance for data volume operations.

### 8.19.9. Uploading local disk images by using the virtctl tool

You can upload a locally stored disk image to a new or existing data volume by using the **virtctl** command-line utility.

#### 8.19.9.1. Prerequisites

- **Enable** the `kubevirt-virtctl` package.
- If you require scratch space according to the [CDI supported operations matrix](?), you must first define a storage class or prepare CDI scratch space for this operation to complete successfully.

#### 8.19.9.2. About data volumes

**DataVolume** objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

#### 8.19.9.3. Creating an upload data volume
You can manually create a data volume with an **upload** data source to use for uploading local disk images.

**Procedure**

1. Create a data volume configuration that specifies `spec: source: upload{}`:

   ```yaml
   apiVersion: cdi.kubevirt.io/v1beta1
   kind: DataVolume
   metadata:
     name: <upload-datavolume>
   spec:
     source:
       upload: {}
   pvc:
     accessModes:
     - ReadWriteOnce
     resources:
       requests:
         storage: <2Gi>
   
   1. The name of the data volume.
   2. The size of the data volume. Ensure that this value is greater than or equal to the size of the disk that you upload.

2. Create the data volume by running the following command:

   ```bash
   $ oc create -f <upload-datavolume>.yaml
   
   8.19.9.4. Uploading a local disk image to a data volume
   
   You can use the **virtctl** CLI utility to upload a local disk image from a client machine to a data volume (DV) in your cluster. You can use a DV that already exists in your cluster or create a new DV during this procedure.

   **NOTE**

   After you upload a local disk image, you can add it to a virtual machine.

**Prerequisites**

- You must have one of the following:
  - A raw virtual machine image file in either ISO or IMG format.
  - A virtual machine image file in QCOW2 format.

- For best results, compress your image file according to the following guidelines before you upload it:
  - Compress a raw image file by using **xz** or **gzip**.
NOTE
Using a compressed raw image file results in the most efficient upload.

- Compress a QCOW2 image file by using the method that is recommended for your client:
  - If you use a Linux client, `sparsify` the QCOW2 file by using the `virt-sparsify` tool.
  - If you use a Windows client, compress the QCOW2 file by using `xz` or `gzip`.

- The `kubevirt-virtctl` package must be installed on the client machine.
- The client machine must be configured to trust the OpenShift Container Platform router’s certificate.

**Procedure**

1. Identify the following items:
   - The name of the upload data volume that you want to use. If this data volume does not exist, it is created automatically.
   - The size of the data volume, if you want it to be created during the upload procedure. The size must be greater than or equal to the size of the disk image.
   - The file location of the virtual machine disk image that you want to upload.

2. Upload the disk image by running the `virtctl image-upload` command. Specify the parameters that you identified in the previous step. For example:

   ```
   $ virtctl image-upload dv <datavolume_name> \ 1
   --size=<datavolume_size> \ 2
   --image-path=/path/to/image> \ 3
   
   1 The name of the data volume.
   2 The size of the data volume. For example: `--size=500Mi, --size=1G`
   3 The file path of the virtual machine disk image.
   
   NOTE
   - If you do not want to create a new data volume, omit the `--size` parameter and include the `--no-create` flag.
   - When uploading a disk image to a PVC, the PVC size must be larger than the size of the uncompressed virtual disk.
   - To allow insecure server connections when using HTTPS, use the `--insecure` parameter. Be aware that when you use the `--insecure` flag, the authenticity of the upload endpoint is **not** verified.

3. Optional. To verify that a data volume was created, view all data volumes by running the following command:  

8.19.9.5. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
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<td>✓ QCOW2**</td>
<td>✓ QCOW2 *</td>
<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
</tr>
<tr>
<td></td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>□ GZ</td>
<td>□ GZ</td>
</tr>
<tr>
<td></td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>□ XZ</td>
<td>□ XZ</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
</tr>
<tr>
<td></td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>□ GZ</td>
<td>□ GZ</td>
</tr>
<tr>
<td></td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>□ XZ</td>
<td>□ XZ</td>
</tr>
</tbody>
</table>

✓ Supported operation
☐ Unsupported operation
* Requires scratch space
** Requires scratch space if a custom certificate authority is required

8.19.9.6. Additional resources

- Configure preallocation mode to improve write performance for data volume operations.

8.19.10. Uploading a local disk image to a block storage data volume

You can upload a local disk image into a block data volume by using the virtctl command-line utility.

In this workflow, you create a local block device to use as a persistent volume, associate this block volume with an upload data volume, and use virtctl to upload the local disk image into the data volume.

8.19.10.1. Prerequisites

- Enable the kubevirt-virtctl package.

- If you require scratch space according to the CDI supported operations matrix, you must first define a storage class or prepare CDI scratch space for this operation to complete successfully.

8.19.10.2. About data volumes

DataVolume objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.19.10.3. About block persistent volumes
A block persistent volume (PV) is a PV that is backed by a raw block device. These volumes do not have a file system and can provide performance benefits for virtual machines by reducing overhead.

Raw block volumes are provisioned by specifying `volumeMode: Block` in the PV and persistent volume claim (PVC) specification.

### 8.19.10.4. Creating a local block persistent volume

Create a local block persistent volume (PV) on a node by populating a file and mounting it as a loop device. You can then reference this loop device in a PV manifest as a Block volume and use it as a block device for a virtual machine image.

**Procedure**

1. Log in as `root` to the node on which to create the local PV. This procedure uses `node01` for its examples.

2. Create a file and populate it with null characters so that it can be used as a block device. The following example creates a file `loop10` with a size of 2Gb (20 100Mb blocks):

   ```bash
   $ dd if=/dev/zero of=<loop10> bs=100M count=20
   ```

3. Mount the `loop10` file as a loop device.

   ```bash
   $ losetup </dev/loop10>d3 <loop10>
   ```

   1. File path where the loop device is mounted.
   2. The file created in the previous step to be mounted as the loop device.

4. Create a `PersistentVolume` manifest that references the mounted loop device.

   ```yaml
   kind: PersistentVolume
   apiVersion: v1
   metadata:
     name: <local-block-pv10>
     annotations:
   spec:
     local:
       path: </dev/loop10>
     capacity:
       storage: <2Gi>
     volumeMode: Block
     storageClassName: local
     accessModes:
     - ReadWriteOnce
     persistentVolumeReclaimPolicy: Delete
     nodeAffinity:
       required:
         nodeSelectorTerms:
         - matchExpressions:
           - key: kubernetes.io/hostname
   ```
The path of the loop device on the node.

2. Specifies it is a block PV.

3. Optional: Set a storage class for the PV. If you omit it, the cluster default is used.

4. The node on which the block device was mounted.

5. Create the block PV.

   # oc create -f <local-block-pv10.yaml>

   # The file name of the persistent volume created in the previous step.

### 8.19.10.5. Creating an upload data volume

You can manually create a data volume with an upload data source to use for uploading local disk images.

**Procedure**

1. Create a data volume configuration that specifies spec: source: upload{):

   ```yaml
   apiVersion: cdi.kubevirt.io/v1beta1
   kind: DataVolume
   metadata:
     name: <upload-datavolume>
   spec:
     source:
       upload: {}
   pvc:
     accessModes:
       - ReadWriteOnce
     resources:
       requests:
         storage: <2Gi>
   ```

   1. The name of the data volume.
   2. The size of the data volume. Ensure that this value is greater than or equal to the size of the disk that you upload.

2. Create the data volume by running the following command:

   ```bash
   $ oc create -f <upload-datavolume>.yaml
   ```

### 8.19.10.6. Uploading a local disk image to a data volume
You can use the `virtctl` CLI utility to upload a local disk image from a client machine to a data volume (DV) in your cluster. You can use a DV that already exists in your cluster or create a new DV during this procedure.

**NOTE**

After you upload a local disk image, you can add it to a virtual machine.

**Prerequisites**

- You must have one of the following:
  - A raw virtual machine image file in either ISO or IMG format.
  - A virtual machine image file in QCOW2 format.
- For best results, compress your image file according to the following guidelines before you upload it:
  - Compress a raw image file by using `xz` or `gzip`.

**NOTE**

Using a compressed raw image file results in the most efficient upload.

- Compress a QCOW2 image file by using the method that is recommended for your client:
  - If you use a Linux client, `sparsify` the QCOW2 file by using the `virt-sparsify` tool.
  - If you use a Windows client, compress the QCOW2 file by using `xz` or `gzip`.
- The `kubevirt-virtctl` package must be installed on the client machine.
- The client machine must be configured to trust the OpenShift Container Platform router’s certificate.

**Procedure**

1. Identify the following items:
   - The name of the upload data volume that you want to use. If this data volume does not exist, it is created automatically.
   - The size of the data volume, if you want it to be created during the upload procedure. The size must be greater than or equal to the size of the disk image.
   - The file location of the virtual machine disk image that you want to upload.

2. Upload the disk image by running the `virtctl image-upload` command. Specify the parameters that you identified in the previous step. For example:

   ```sh
   $ virtctl image-upload dv <datavolume_name> \ 1
   --size=<datavolume_size> \ 2
   --image-path=</path/to/image> \ 3
   ```
1. The name of the data volume.
2. The size of the data volume. For example: `--size=500Mi`, `--size=1G`
3. The file path of the virtual machine disk image.

**NOTE**
- If you do not want to create a new data volume, omit the `--size` parameter and include the `--no-create` flag.
- When uploading a disk image to a PVC, the PVC size must be larger than the size of the uncompressed virtual disk.
- To allow insecure server connections when using HTTPS, use the `--insecure` parameter. Be aware that when you use the `--insecure` flag, the authenticity of the upload endpoint is not verified.

3. Optional. To verify that a data volume was created, view all data volumes by running the following command:

   ```bash
   $ oc get dvs
   ```

### 8.19.10.7. CDI supported operations matrix

This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

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</tr>
</tbody>
</table>

- ✓ Supported operation
- ☐ Unsupported operation
- * Requires scratch space
- ** Requires scratch space if a custom certificate authority is required

### 8.19.10.8. Additional resources

- Configure preallocation mode to improve write performance for data volume operations.
8.19.11. Managing virtual machine snapshots

You can create and delete virtual machine (VM) snapshots for VMs, whether the VMs are powered off (offline) or on (online). You can only restore to a powered off (offline) VM. OpenShift Virtualization supports VM snapshots on the following:

- Red Hat OpenShift Data Foundation
- Any other storage provider with the Container Storage Interface (CSI) driver that supports the Kubernetes Volume Snapshot API

Online snapshots have a default time deadline of five minutes (5m) that can be changed, if needed.

**IMPORTANT**

Online snapshots are supported for virtual machines that have hot-plugged virtual disks. However, hot-plugged disks that are not in the virtual machine specification are not included in the snapshot.

**NOTE**

To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM’s file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

8.19.11.1. About virtual machine snapshots

A snapshot represents the state and data of a virtual machine (VM) at a specific point in time. You can use a snapshot to restore an existing VM to a previous state (represented by the snapshot) for backup and disaster recovery or to rapidly roll back to a previous development version.

A VM snapshot is created from a VM that is powered off (Stopped state) or powered on (Running state).

When taking a snapshot of a running VM, the controller checks that the QEMU guest agent is installed and running. If so, it freezes the VM file system before taking the snapshot, and thaws the file system after the snapshot is taken.

The snapshot stores a copy of each Container Storage Interface (CSI) volume attached to the VM and a copy of the VM specification and metadata. Snapshots cannot be changed after creation.

With the VM snapshots feature, cluster administrators and application developers can:

- Create a new snapshot
- List all snapshots attached to a specific VM
- Restore a VM from a snapshot
- Delete an existing VM snapshot
8.19.11.1. Virtual machine snapshot controller and custom resource definitions (CRDs)

The VM snapshot feature introduces three new API objects defined as CRDs for managing snapshots:

- **VirtualMachineSnapshot**: Represents a user request to create a snapshot. It contains information about the current state of the VM.

- **VirtualMachineSnapshotContent**: Represents a provisioned resource on the cluster (a snapshot). It is created by the VM snapshot controller and contains references to all resources required to restore the VM.

- **VirtualMachineRestore**: Represents a user request to restore a VM from a snapshot.

The VM snapshot controller binds a VirtualMachineSnapshotContent object with the VirtualMachineSnapshot object for which it was created, with a one-to-one mapping.

8.19.11.2. Installing QEMU guest agent on a Linux virtual machine

The qemu-guest-agent is widely available and available by default in Red Hat virtual machines. Install the agent and start the service.

To check if your virtual machine (VM) has the QEMU guest agent installed and running, verify that AgentConnected is listed in the VM spec.

**NOTE**

To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM’s file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

**Procedure**

1. Access the virtual machine command line through one of the consoles or by SSH.

2. Install the QEMU guest agent on the virtual machine:

   ```
   $ yum install -y qemu-guest-agent
   ```

3. Ensure the service is persistent and start it:

   ```
   $ systemctl enable --now qemu-guest-agent
   ```

8.19.11.3. Installing QEMU guest agent on a Windows virtual machine

For Windows virtual machines, the QEMU guest agent is included in the VirtIO drivers. Install the drivers on an existing or new Windows system.

To check if your virtual machine (VM) has the QEMU guest agent installed and running, verify that AgentConnected is listed in the VM spec.
NOTE

To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM’s file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

8.19.11.3.1. Installing VirtIO drivers on an existing Windows virtual machine

Install the VirtIO drivers from the attached SATA CD drive to an existing Windows virtual machine.

NOTE

This procedure uses a generic approach to adding drivers to Windows. The process might differ slightly between versions of Windows. See the installation documentation for your version of Windows for specific installation steps.

Procedure

1. Start the virtual machine and connect to a graphical console.
2. Log in to a Windows user session.
3. Open Device Manager and expand Other devices to list any Unknown device.
   a. Open the Device Properties to identify the unknown device. Right-click the device and select Properties.
   b. Click the Details tab and select Hardware Ids in the Property list.
   c. Compare the Value for the Hardware Ids with the supported VirtIO drivers.
4. Right-click the device and select Update Driver Software.
5. Click Browse my computer for driver software and browse to the attached SATA CD drive, where the VirtIO drivers are located. The drivers are arranged hierarchically according to their driver type, operating system, and CPU architecture.
6. Click Next to install the driver.
7. Repeat this process for all the necessary VirtIO drivers.
8. After the driver installs, click Close to close the window.
9. Reboot the virtual machine to complete the driver installation.

8.19.11.3.2. Installing VirtIO drivers during Windows installation

Install the VirtIO drivers from the attached SATA CD driver during Windows installation.
NOTE

This procedure uses a generic approach to the Windows installation and the installation method might differ between versions of Windows. See the documentation for the version of Windows that you are installing.

Procedure

1. Start the virtual machine and connect to a graphical console.
2. Begin the Windows installation process.
3. Select the Advanced installation.
4. The storage destination will not be recognized until the driver is loaded. Click Load driver.
5. The drivers are attached as a SATA CD drive. Click OK and browse the CD drive for the storage driver to load. The drivers are arranged hierarchically according to their driver type, operating system, and CPU architecture.
6. Repeat the previous two steps for all required drivers.
7. Complete the Windows installation.

8.19.11.4. Creating a virtual machine snapshot in the web console

You can create a virtual machine (VM) snapshot by using the web console.

NOTE

To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM’s file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

NOTE

The VM snapshot only includes disks that meet the following requirements:

- Must be either a data volume or persistent volume claim
- Belong to a storage class that supports Container Storage Interface (CSI) volume snapshots

Procedure

1. Click Workloads → Virtualization from the side menu.
2. Click the Virtual Machines tab.
3. Select a virtual machine to open the Virtual Machine Overview screen.
4. If the virtual machine is running, click **Actions → Stop Virtual Machine** to power it down.

5. Click the **Snapshots** tab and then click **Take Snapshot**.

6. Fill in the **Snapshot Name** and optional **Description** fields.

7. Expand **Disks included in this Snapshot** to see the storage volumes to be included in the snapshot.

8. If your VM has disks that cannot be included in the snapshot and you still wish to proceed, select the **I am aware of this warning and wish to proceed** checkbox.

9. Click **Save**.

**8.19.11.5. Creating an virtual machine snapshot in the CLI**

You can create a virtual machine (VM) snapshot for an offline or online VM by creating a **VirtualMachineSnapshot** object. Kubevirt will coordinate with the QEMU guest agent to create a snapshot of the online VM.

**NOTE**

To create snapshots of an online (Running state) VM with the highest integrity, install the QEMU guest agent.

The QEMU guest agent takes a consistent snapshot by attempting to quiesce the VM's file system as much as possible, depending on the system workload. This ensures that in-flight I/O is written to the disk before the snapshot is taken. If the guest agent is not present, quiescing is not possible and a best-effort snapshot is taken. The conditions under which the snapshot was taken are reflected in the snapshot indications that are displayed in the web console or CLI.

**Prerequisites**

- Ensure that the persistent volume claims (PVCs) are in a storage class that supports Container Storage Interface (CSI) volume snapshots.
- Install the OpenShift CLI (**oc**).
- Optional: Power down the VM for which you want to create a snapshot.

**Procedure**

1. Create a YAML file to define a **VirtualMachineSnapshot** object that specifies the name of the new **VirtualMachineSnapshot** and the name of the source VM.

   For example:

   ```yaml
   apiVersion: snapshot.kubevirt.io/v1alpha1
   kind: VirtualMachineSnapshot
   metadata:
     name: my-vmsnapshot
   spec:
     source:
   ```
1. The name of the new `VirtualMachineSnapshot` object.

2. The name of the source VM.

2. Create the `VirtualMachineSnapshot` resource. The snapshot controller creates a `VirtualMachineSnapshotContent` object, binds it to the `VirtualMachineSnapshot` and updates the `status` and `readyToUse` fields of the `VirtualMachineSnapshot` object.

   ```
   $ oc create -f <my-vmsnapshot>.yaml
   ```

3. Optional: If you are taking an online snapshot, you can use the `wait` command and monitor the status of the snapshot:

   a. Enter the following command:

   ```
   $ kubectl wait my-vm my-vmsnapshot --for condition=Ready
   ```

   b. Verify the status of the snapshot:

   - **InProgress** - The online snapshot operation is still in progress.
   - **Succeeded** - The online snapshot operation completed successfully.
   - **Failed** - The online snapshot operation failed.

**NOTE**

Online snapshots have a default time deadline of five minutes (5m). If the snapshot does not complete successfully in five minutes, the status is set to `failed`. Afterwards, the file system will be thawed and the VM unfrozen but the status remains `failed` until you delete the failed snapshot image.

To change the default time deadline, add the `FailureDeadline` attribute to the VM snapshot spec with the time designated in minutes (m) or in seconds (s) that you want to specify before the snapshot operation times out.

To set no deadline, you can specify 0, though this is generally not recommended, as it can result in an unresponsive VM.

If you do not specify a unit of time such as m or s, the default is seconds (s).

**Verification**

1. Verify that the `VirtualMachineSnapshot` object is created and bound with `VirtualMachineSnapshotContent`. The `readyToUse` flag must be set to `true`.

   ```
   $ oc describe vmsnapshot <my-vmsnapshot>
   ```
Example output

```yaml
apiVersion: snapshot.kubevirt.io/v1alpha1
kind: VirtualMachineSnapshot
metadata:
  creationTimestamp: "2020-09-30T14:41:51Z"
finalizers:
- snapshot.kubevirt.io/vmsnapshot-protection
generation: 5
name: mysnap
namespace: default
resourceVersion: "3897"
selfLink:
  /apis/snapshot.kubevirt.io/v1alpha1/namespaces/default/virtualmachinesnapshots/my-vmsnapshot
uid: 28eedf08-5d6a-42c1-969c-2eda58e2a78d
spec:
source:
  apiGroup: kubevirt.io
  kind: VirtualMachine
  name: my-vm
status:
conditions:
- lastProbeTime: null
  lastTransitionTime: "2020-09-30T14:42:03Z"
  reason: Operation complete
  status: "False"
  type: Progressing
- lastProbeTime: null
  lastTransitionTime: "2020-09-30T14:42:03Z"
  reason: Operation complete
  status: "True"
  type: Ready
  creationTime: "2020-09-30T14:42:03Z"
  readyToUse: true
sourceUID: 355897f3-73a0-4ec4-83d3-3c2df9486f4f
virtualMachineSnapshotContentName: vmsnapshot-content-28eedf08-5d6a-42c1-969c-2eda58e2a78d
```

1. **The status field of the Progressing condition** specifies if the snapshot is still being created.

2. **The status field of the Ready condition** specifies if the snapshot creation process is complete.

3. **Specifies if the snapshot is ready to be used.**

4. **Specifies that the snapshot is bound to a VirtualMachineSnapshotContent object created by the snapshot controller.**

2. Check the `spec:volumeBackups` property of the VirtualMachineSnapshotContent resource to verify that the expected PVCs are included in the snapshot.

**8.19.11.6. Verifying online snapshot creation with snapshot indications**
Snapshot indications are contextual information about online virtual machine (VM) snapshot operations. Indications are not available for offline virtual machine (VM) snapshot operations. Indications are helpful in describing details about the online snapshot creation.

Prerequisites

- To view indications, you must have attempted to create an online VM snapshot using the CLI or the web console.

Procedure

1. Display the output from the snapshot indications by doing one of the following:
   - For snapshots created with the CLI, view indicator output in the `VirtualMachineSnapshot` object YAML, in the `status` field.
   - For snapshots created using the web console, click `VirtualMachineSnapshot > Status` in the `Snapshot details` screen.

2. Verify the status of your online VM snapshot:
   - **Online** indicates that the VM was running during online snapshot creation.
   - **NoGuestAgent** indicates that the QEMU guest agent was not running during online snapshot creation. The QEMU guest agent could not be used to freeze and thaw the file system, either because the QEMU guest agent was not installed or running or due to another error.

8.19.11.7. Restoring a virtual machine from a snapshot in the web console

You can restore a virtual machine (VM) to a previous configuration represented by a snapshot in the web console.

Procedure

1. Click **Workloads** → **Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** screen.

4. If the virtual machine is running, click **Actions** → **Stop Virtual Machine** to power it down.

5. Click the **Snapshots** tab. The page displays a list of snapshots associated with the virtual machine.

6. Choose one of the following methods to restore a VM snapshot:
   - a. For the snapshot that you want to use as the source to restore the VM, click **Restore**.
   - b. Select a snapshot to open the **Snapshot Details** screen and click **Actions** → **Restore Virtual Machine Snapshot**.

7. In the confirmation pop-up window, click **Restore** to restore the VM to its previous configuration represented by the snapshot.
8.19.11.8. Restoring a virtual machine from a snapshot in the CLI

You can restore an existing virtual machine (VM) to a previous configuration by using a VM snapshot. You can only restore from an offline VM snapshot.

Prerequisites

- Install the OpenShift CLI (oc).
- Power down the VM you want to restore to a previous state.

Procedure

1. Create a YAML file to define a `VirtualMachineRestore` object that specifies the name of the VM you want to restore and the name of the snapshot to be used as the source. For example:

   ```yaml
   apiVersion: snapshot.kubevirt.io/v1alpha1
   kind: VirtualMachineRestore
   metadata:
     name: my-vmrestore
   spec:
     target:
       apiGroup: kubevirt.io
       kind: VirtualMachine
       name: my-vm
     virtualMachineSnapshotName: my-vmsnapshot
   ```

   1. The name of the new `VirtualMachineRestore` object.
   2. The name of the target VM you want to restore.
   3. The name of the `VirtualMachineSnapshot` object to be used as the source.

2. Create the `VirtualMachineRestore` resource. The snapshot controller updates the status fields of the `VirtualMachineRestore` object and replaces the existing VM configuration with the snapshot content.

   ```bash
   $ oc create -f <my-vmrestore>.yaml
   ```

Verification

- Verify that the VM is restored to the previous state represented by the snapshot. The `complete` flag must be set to `true`.

   ```bash
   $ oc get vmrestore <my-vmrestore>
   ```

Example output

```yaml
apiVersion: snapshot.kubevirt.io/v1alpha1
kind: VirtualMachineRestore
metadata:
  creationTimestamp: "2020-09-30T14:46:27Z"
```
Specifies if the process of restoring the VM to the state represented by the snapshot is complete.

The status field of the Progressing condition specifies if the VM is still being restored.

The status field of the Ready condition specifies if the VM restoration process is complete.

8.19.11.9. Deleting a virtual machine snapshot in the web console
You can delete an existing virtual machine snapshot by using the web console.

### Procedure

1. Click **Workloads → Virtualization** from the side menu.

2. Click the **Virtual Machines** tab.

3. Select a virtual machine to open the **Virtual Machine Overview** screen.

4. Click the **Snapshots** tab. The page displays a list of snapshots associated with the virtual machine.

5. Choose one of the following methods to delete a virtual machine snapshot:
   - a. Click the Options menu of the virtual machine snapshot that you want to delete and select **Delete Virtual Machine Snapshot**
   - b. Select a snapshot to open the **Snapshot Details** screen and click **Actions → Delete Virtual Machine Snapshot**.

6. In the confirmation pop-up window, click **Delete** to delete the snapshot.

### 8.19.11.10. Deleting a virtual machine snapshot in the CLI

You can delete an existing virtual machine (VM) snapshot by deleting the appropriate **VirtualMachineSnapshot** object.

#### Prerequisites
- Install the OpenShift CLI (**oc**).

#### Procedure
- Delete the **VirtualMachineSnapshot** object. The snapshot controller deletes the **VirtualMachineSnapshot** along with the associated **VirtualMachineSnapshotContent** object.

```
$ oc delete vmsnapshot <my-vmsnapshot>
```

#### Verification
- Verify that the snapshot is deleted and no longer attached to this VM:

```
$ oc get vmsnapshot
```

### 8.19.11.11. Additional resources
- **CSI Volume Snapshots**

### 8.19.12. Moving a local virtual machine disk to a different node

Virtual machines that use local volume storage can be moved so that they run on a specific node.
You might want to move the virtual machine to a specific node for the following reasons:

- The current node has limitations to the local storage configuration.
- The new node is better optimized for the workload of that virtual machine.

To move a virtual machine that uses local storage, you must clone the underlying volume by using a data volume. After the cloning operation is complete, you can edit the virtual machine configuration so that it uses the new data volume, or add the new data volume to another virtual machine.

TIP

When you enable preallocation globally, or for a single data volume, the Containerized Data Importer (CDI) preallocates disk space during cloning. Preallocation enhances write performance. For more information, see Using preallocation for data volumes.

NOTE

Users without the cluster-admin role require additional user permissions to clone volumes across namespaces.

8.19.12.1. Cloning a local volume to another node

You can move a virtual machine disk so that it runs on a specific node by cloning the underlying persistent volume claim (PVC).

To ensure the virtual machine disk is cloned to the correct node, you must either create a new persistent volume (PV) or identify one on the correct node. Apply a unique label to the PV so that it can be referenced by the data volume.

NOTE

The destination PV must be the same size or larger than the source PVC. If the destination PV is smaller than the source PVC, the cloning operation fails.

Prerequisites

- The virtual machine must not be running. Power down the virtual machine before cloning the virtual machine disk.

Procedure

1. Either create a new local PV on the node, or identify a local PV already on the node:

   - Create a local PV that includes the `nodeAffinity.nodeSelectorTerms` parameters. The following manifest creates a `10Gi` local PV on `node01`.

```yaml
kind: PersistentVolume
apiVersion: v1
metadata:
  name: <destination-pv> 1
annotations:
spec:
  accessModes:
    - ReadWriteOnce
```
The name of the PV.

2. The size of the PV. You must allocate enough space, or the cloning operation fails. The size must be the same as or larger than the source PVC.

3. The mount path on the node.

4. The name of the node where you want to create the PV.

Identify a PV that already exists on the target node. You can identify the node where a PV is provisioned by viewing the nodeAffinity field in its configuration:

```bash
$ oc get pv <destination-pv> -o yaml
```

The following snippet shows that the PV is on `node01`:

**Example output**

```yaml
...  
spec:  
  nodeAffinity:  
    required:  
      nodeSelectorTerms:  
        - matchExpressions:  
          - key: kubernetes.io/hostname  
            operator: In  
            values:  
              - node01  
...  
```

1. The `kubernetes.io/hostname` key uses the node hostname to select a node.

2. The hostname of the node.

2. Add a unique label to the PV:

```bash
$ oc label pv <destination-pv> node=node01
```
3. Create a data volume manifest that references the following:

- The PVC name and namespace of the virtual machine.
- The label you applied to the PV in the previous step.
- The size of the destination PV.

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: <clone-datavolume>
spec:
source:
pvc:
  name: "<source-vm-disk>"
  namespace: "<source-namespace>"
pvc:
  accessModes:
  - ReadWriteOnce
selector:
  matchLabels:
    node: node01
resources:
  requests:
    storage: <10Gi>
```

1. The name of the new data volume.
2. The name of the source PVC. If you do not know the PVC name, you can find it in the virtual machine configuration: `spec.volumes.persistentVolumeClaim.claimName`.
3. The namespace where the source PVC exists.
4. The label that you applied to the PV in the previous step.
5. The size of the destination PV.

4. Start the cloning operation by applying the data volume manifest to your cluster:

```bash
$ oc apply -f <clone-datavolume.yaml>
```

The data volume clones the PVC of the virtual machine into the PV on the specific node.

8.19.13. Expanding virtual storage by adding blank disk images

You can increase your storage capacity or create new data partitions by adding blank disk images to OpenShift Virtualization.

8.19.13.1. About data volumes

`DataVolume` objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization,
and they prevent a virtual machine from being started before the PVC has been prepared.

8.19.13.2. Creating a blank disk image with data volumes

You can create a new blank disk image in a persistent volume claim by customizing and deploying a data volume configuration file.

Prerequisites

- At least one available persistent volume.
- Install the OpenShift CLI (oc).

Procedure

1. Edit the data volume configuration file:

   ```
   apiVersion: cdi.kubevirt.io/v1beta1
   kind: DataVolume
   metadata:
     name: blank-image-datavolume
   spec:
     source:
       blank: {}
     pvc:
       # Optional: Set the storage class or omit to accept the default
       # storageClassName: "hostpath"
       accessModes:
       - ReadWriteOnce
     resources:
     requests:
       storage: 500Mi
   ```

2. Create the blank disk image by running the following command:

   ```
   $ oc create -f <blank-image-datavolume>.yaml
   ```

8.19.13.3. Template: Data volume configuration file for blank disk images

**blank-image-datavolume.yaml**

```
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: blank-image-datavolume
spec:
  source:
    blank: {}
  pvc:
  # Optional: Set the storage class or omit to accept the default
  # storageClassName: "hostpath"
  accessModes:
  - ReadWriteOnce
  resources:
  requests:
    storage: 500Mi
```
8.19.13.4. Additional resources

- Configure preallocation mode to improve write performance for data volume operations.


Smart-cloning is a built-in feature of OpenShift Container Platform Storage (OCS), designed to enhance performance of the cloning process. Clones created with smart-cloning are faster and more efficient than host-assisted cloning.

You do not need to perform any action to enable smart-cloning, but you need to ensure your storage environment is compatible with smart-cloning to use this feature.

When you create a data volume with a persistent volume claim (PVC) source, you automatically initiate the cloning process. You always receive a clone of the data volume if your environment supports smart-cloning or not. However, you will only receive the performance benefits of smart cloning if your storage provider supports smart-cloning.


When a data volume is smart-cloned, the following occurs:

1. A snapshot of the source persistent volume claim (PVC) is created.
2. A PVC is created from the snapshot.
3. The snapshot is deleted.

8.19.14.2. Cloning a data volume

Prerequisites

For smart-cloning to occur, the following conditions are required:

- Your storage provider must support snapshots.
- The source and target PVCs must be defined to the same storage class.
- The source and target PVCs share the same volumeMode.
- The VolumeSnapshotClass object must reference the storage class defined to both the source and target PVCs.

Procedure

To initiate cloning of a data volume:

1. Create a YAML file for a DataVolume object that specifies the name of the new data volume and the name and namespace of the source PVC. In this example, because you specify the storage API, there is no need to specify accessModes or volumeMode. The optimal values will be calculated for you automatically.
The name of the new data volume.

The namespace where the source PVC exists.

The name of the source PVC.

Specifies allocation with the storage API

The size of the new data volume.

2. Start cloning the PVC by creating the data volume:

```bash
$ oc create -f <cloner-datavolume>.yaml
```

**NOTE**

Data volumes prevent a virtual machine from starting before the PVC is prepared, so you can create a virtual machine that references the new data volume while the PVC clones.

8.19.14.3. Additional resources

- Cloning the persistent volume claim of a virtual machine disk into a new data volume
- Configure preallocation mode to improve write performance for data volume operations.
- Customizing the storage profile

8.19.15. Creating and using boot sources

A boot source contains a bootable operating system (OS) and all of the configuration settings for the OS, such as drivers.

You use a boot source to create virtual machine templates with specific configurations. These templates can be used to create any number of available virtual machines.

8.19.15.1. About virtual machines and boot sources

```yaml
apiVersion: cdi.kubevirt.io/v1beta1
kind: DataVolume
metadata:
  name: <cloner-datavolume> 1
spec:
source:
pvc:
  namespace: "<source-namespace>" 2
  name: "<my-favorite-vm-disk>" 3
storage: 4
resources:
  requests:
    storage: <2Gi> 5
```
Virtual machines consist of a virtual machine definition and one or more disks that are backed by data volumes. Virtual machine templates enable you to create virtual machines using predefined virtual machine specifications.

Every virtual machine template requires a boot source, which is a fully configured virtual machine disk image including configured drivers. Each virtual machine template contains a virtual machine definition with a pointer to the boot source. Each boot source has a predefined name and namespace. For some operating systems, a boot source is automatically provided. If it is not provided, then an administrator must prepare a custom boot source.

Provided boot sources are updated automatically to the latest version of the operating system. For auto-updated boot sources, persistent volume claims (PVCs) are created with the cluster’s default storage class. If you select a different default storage class after configuration, you must delete the existing data volumes in the cluster namespace that are configured with the previous default storage class.

To use the boot sources feature, install the latest release of OpenShift Virtualization. The namespace `openshift-virtualization-os-images` enables the feature and is installed with the OpenShift Virtualization Operator. Once the boot source feature is installed, you can create boot sources, attach them to templates, and create virtual machines from the templates.

Define a boot source by using a persistent volume claim (PVC) that is populated by uploading a local file, cloning an existing PVC, importing from a registry, or by URL. Attach a boot source to a virtual machine template by using the web console. After the boot source is attached to a virtual machine template, you create any number of fully configured ready-to-use virtual machines from the template.

### 8.19.15.2. Importing a Red Hat Enterprise Linux image as a boot source

You can import a Red Hat Enterprise Linux (RHEL) image as a boot source by specifying the URL address for the image.

**Prerequisites**

- You must have access to the web server with the operating system image. For example: Red Hat Enterprise Linux web page with images.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.
2. Click the **Templates** tab.
3. Identify the RHEL template for which you want to configure a boot source and click **Add source**.
4. In the **Add boot source to template** window, select **Import via URL (creates PVC)** from the **Boot source type** list.
5. Click **RHEL download page** to access the Red Hat Customer Portal. A list of available installers and images is displayed on the Download Red Hat Enterprise Linux page.
6. Identify the Red Hat Enterprise Linux KVM guest image that you want to download. Right-click **Download Now**, and copy the URL for the image.
7. In the **Add boot source to template** window, paste the copied URL of the guest image into the **Import URL** field, and click **Save and import**.
Verification

To verify that a boot source was added to the template:

1. Click the Templates tab.

2. Confirm that the tile for this template displays a green checkmark.

You can now use this template to create RHEL virtual machines.

8.19.15.3. Adding a boot source for a virtual machine template

A boot source can be configured for any virtual machine template that you want to use for creating virtual machines or custom templates. When virtual machine templates are configured with a boot source, they are labeled Available in the Templates tab. After you add a boot source to a template, you can create a new virtual machine from the template.

There are four methods for selecting and adding a boot source in the web console:

- Upload local file (creates PVC)
- Import via URL (creates PVC)
- Clone existing PVC (creates PVC)
- Import via Registry (creates PVC)

Prerequisites

- To add a boot source, you must be logged in as a user with the os-images.kubevirt.io:edit RBAC role or as an administrator. You do not need special privileges to create a virtual machine from a template with a boot source added.

- To upload a local file, the operating system image file must exist on your local machine.

- To import via URL, access to the web server with the operating system image is required. For example: the Red Hat Enterprise Linux web page with images.

- To clone an existing PVC, access to the project with a PVC is required.

- To import via registry, access to the container registry is required.

Procedure

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.

2. Click the Templates tab.

3. Identify the virtual machine template for which you want to configure a boot source and click Add source.

4. In the Add boot source to template window, click Select boot source, select a method for creating a persistent volume claim (PVC): Upload local file, Import via URL, Clone existing PVC, or Import via Registry.

5. Optional: Click This is a CD-ROM boot source to mount a CD-ROM and use it to install the operating system on to an empty disk. The additional empty disk is automatically created and
mounted by OpenShift Virtualization. If the additional disk is not needed, you can remove it when you create the virtual machine.

6. Enter a value for **Persistent Volume Claim size** to specify the PVC size that is adequate for the uncompressed image and any additional space that is required.

   a. Optional: Enter a name for **Source provider** to associate the name with this template.

   b. Optional: **Advanced Storage settings:** Click **Storage class** and select the storage class that is used to create the disk. Typically, this storage class is the default storage class that is created for use by all PVCs.

   **NOTE**

   Provided boot sources are updated automatically to the latest version of the operating system. For auto-updated boot sources, persistent volume claims (PVCs) are created with the cluster’s default storage class. If you select a different default storage class after configuration, you must delete the existing data volumes in the cluster namespace that are configured with the previous default storage class.

   c. Optional: **Advanced Storage settings:** Click **Access mode** and select an access mode for the persistent volume:

      - **Single User (RWO)** mounts the volume as read-write by a single node.
      - **Shared Access (RWX)** mounts the volume as read-write by many nodes.
      - **Read Only (ROX)** mounts the volume as read-only by many nodes.

   d. Optional: **Advanced Storage settings:** Click **Volume mode** if you want to select **Block** instead of the default value **Filesystem.** OpenShift Virtualization can statically provision raw block volumes. These volumes do not have a file system, and can provide performance benefits for applications that either write to the disk directly or implement their own storage service.

7. Select the appropriate method to save your boot source:

   a. Click **Save and upload** if you uploaded a local file.

   b. Click **Save and import** if you imported content from a URL or the registry.

   c. Click **Save and clone** if you cloned an existing PVC.

Your custom virtual machine template with a boot source is listed in the **Templates** tab, and you can create virtual machines by using this template.

### 8.19.15.4. Creating a virtual machine from a template with an attached boot source

After you add a boot source to a template, you can create a new virtual machine from the template.

**Procedure**

1. In the OpenShift Container Platform web console, click **Workloads > Virtualization** in the side menu.
2. From the Virtual Machines tab or the Templates tab, click Create and select Virtual Machine with Wizard.

3. In the Select a template step, select an OS from the Operating System list that has the (Source available) label next to the OS and version name. The (Source available) label indicates that a boot source is available for this OS.

4. Click Review and Confirm.

5. Review your virtual machine settings and edit them, if required.

6. Click Create Virtual Machine to create your virtual machine. The Successfully created virtual machine page is displayed.

8.19.15.5. Creating a custom boot source

You can prepare a custom disk image, based on an existing disk image, for use as a boot source.

Use this procedure to complete the following tasks:

- Preparing a custom disk image
- Creating a boot source from the custom disk image
- Attaching the boot source to a custom template

Procedure

1. In the OpenShift Virtualization console, click Workloads > Virtualization from the side menu.

2. Click the Templates tab.

3. Click the link in the Source provider column for the template you want to customize. A window displays, indicating that the template currently has a defined source.

4. In the window, click the Customize source link.

5. Click Continue in the About boot source customization window to proceed with customization after reading the information provided about the boot source customization process.

6. On the Prepare boot source customization page, in the Define new template section:
   a. Select the New template namespace field and then choose a project.
   b. Enter the name of the custom template in the New template name field.
   c. Enter the name of the template provider in the New template provider field.
   d. Select the New template support field and then choose the appropriate value, indicating support contacts for the custom template you create.
   e. Select the New template flavor field and then choose the appropriate CPU and memory values for the custom image you create.

7. In the Prepare boot source for customization section, customize the cloud-init YAML script, if needed, to define login credentials. Otherwise, the script generates default credentials for you.
8. Click **Start Customization**. The customization process begins and the **Preparing boot source customization** page displays, followed by the **Customize boot source** page. The **Customize boot source** page displays the output of the running script. When the script completes, your custom image is available.

9. In the **VNC console**, click **show password** in the **Guest login credentials** section. Your login credentials display.

10. When the image is ready for login, sign in with the **VNC Console** by providing the user name and password displayed in the **Guest login credentials** section.

11. Verify the custom image works as expected. If it does, click **Make this boot source available**.

12. In the **Finish customization and make template available** window, select **I have sealed the boot source so it can be used as a template** and then click **Apply**.

13. On the **Finishing boot source customization** page, wait for the template creation process to complete. Click **Navigate to template details** or **Navigate to template list** to view your customized template, created from your custom boot source.

### 8.19.15.6. Additional resources

- Creating virtual machine templates
- Creating a Microsoft Windows boot source from a cloud image
- Customizing existing Microsoft Windows boot sources in OpenShift Container Platform
- Setting a PVC as a boot source for a Microsoft Windows template using the CLI
- Creating boot sources using automated scripting
- Creating a boot source automatically within a pod

### 8.19.16. Hot-plugging virtual disks

Hot-plug and hot-unplug virtual disks when you want to add or remove them without stopping your virtual machine or virtual machine instance. This capability is helpful when you need to add storage to a running virtual machine without incurring down-time.

When you **hot-plug** a virtual disk, you attach a virtual disk to a virtual machine instance while the virtual machine is running.

When you **hot-unplug** a virtual disk, you detach a virtual disk from a virtual machine instance while the virtual machine is running.

Only data volumes and persistent volume claims (PVCs) can be hot-plugged and hot-unplugged. You cannot hot-plug or hot-unplug container disks.

### 8.19.16.1. Hot-plugging a virtual disk using the CLI

Hot-plug virtual disks that you want to attach to a virtual machine instance (VMI) while a virtual machine is running.

**Prerequisites**
You must have a running virtual machine to hot-plug a virtual disk.

You must have at least one data volume or persistent volume claim (PVC) available for hot-plugging.

**Procedure**

Hot-plug a virtual disk by running the following command:

```bash
$ virtctl addvolume <virtual-machine|virtual-machine-instance> --volume-name=<datavolume|PVC> \ 
[-persist] [-serial=<label-name>]
```

- Use the optional **--persist** flag to add the hot-plugged disk to the virtual machine specification as a permanently mounted virtual disk. Stop, restart, or reboot the virtual machine to permanently mount the virtual disk. After specifying the **--persist** flag, you can no longer hot-plug or hot-unplug the virtual disk. The **--persist** flag applies to virtual machines, not virtual machine instances.

- The optional **--serial** flag allows you to add an alphanumeric string label of your choice. This helps you to identify the hot-plugged disk in a guest virtual machine. If you do not specify this option, the label defaults to the name of the hot-plugged data volume or PVC.

**8.19.16.2. Hot-unplugging a virtual disk using the CLI**

Hot-unplug virtual disks that you want to detach from a virtual machine instance (VMI) while a virtual machine is running.

**Prerequisites**

- Your virtual machine must be running.
- You must have at least one data volume or persistent volume claim (PVC) available and hot-plugged.

**Procedure**

Hot-unplug a virtual disk by running the following command:

```bash
$ virtctl removevolume <virtual-machine|virtual-machine-instance> --volume-name=<datavolume|PVC>
```

**8.19.16.3. Hot-plugging a virtual disk using the web console**

Hot-plug virtual disks that you want to attach to a virtual machine instance (VMI) while a virtual machine is running.

**Prerequisites**

- You must have a running virtual machine to hot-plug a virtual disk.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.
2. On the **Virtual Machines** tab, select the running virtual machine to which you want to hot-plug a virtual disk.

3. On the **Disks** tab, click **Add Disk**

4. In the **Add Disk** window, fill in the information for the virtual disk that you want to hot-plug.

5. Click **Add**.

**8.19.16.4. Hot-unplugging a virtual disk using the web console**

Hot-unplug virtual disks that you want to attach to a virtual machine instance (VMI) while a virtual machine is running.

**Prerequisites**

- Your virtual machine must be running with a hot-plugged disk attached.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.

2. On the **Virtual Machines** tab, select the running virtual machine with the disk you want to hot-unplug.

3. On the **Disks** tab, click the **Options menu** of the virtual disk that you want to hot-unplug.

4. Click **Delete**.

**8.19.17. Using container disks with virtual machines**

You can build a virtual machine image into a container disk and store it in your container registry. You can then import the container disk into persistent storage for a virtual machine or attach it directly to the virtual machine for ephemeral storage.

**IMPORTANT**

If you use large container disks, I/O traffic might increase, impacting worker nodes. This can lead to unavailable nodes. You can resolve this by:

- **Pruning DeploymentConfig objects**
- **Configuring garbage collection**

**8.19.17.1. About container disks**

A container disk is a virtual machine image that is stored as a container image in a container image registry. You can use container disks to deliver the same disk images to multiple virtual machines and to create large numbers of virtual machine clones.

A container disk can either be imported into a persistent volume claim (PVC) by using a data volume that is attached to a virtual machine, or attached directly to a virtual machine as an ephemeral **containerDisk** volume.
8.19.17.1.1. Importing a container disk into a PVC by using a data volume

Use the Containerized Data Importer (CDI) to import the container disk into a PVC by using a data volume. You can then attach the data volume to a virtual machine for persistent storage.

8.19.17.1.2. Attaching a container disk to a virtual machine as a containerDisk volume

A containerDisk volume is ephemeral. It is discarded when the virtual machine is stopped, restarted, or deleted. When a virtual machine with a containerDisk volume starts, the container image is pulled from the registry and hosted on the node that is hosting the virtual machine.

Use containerDisk volumes for read-only file systems such as CD-ROMs or for disposable virtual machines.

IMPORTANT

Using containerDisk volumes for read-write file systems is not recommended because the data is temporarily written to local storage on the hosting node. This slows live migration of the virtual machine, such as in the case of node maintenance, because the data must be migrated to the destination node. Additionally, all data is lost if the node loses power or otherwise shuts down unexpectedly.

8.19.17.2. Preparing a container disk for virtual machines

You must build a container disk with a virtual machine image and push it to a container registry before it can used with a virtual machine. You can then either import the container disk into a PVC using a data volume and attach it to a virtual machine, or you can attach the container disk directly to a virtual machine as an ephemeral containerDisk volume.

The size of a disk image inside a container disk is limited by the maximum layer size of the registry where the container disk is hosted.

NOTE

For Red Hat Quay, you can change the maximum layer size by editing the YAML configuration file that is created when Red Hat Quay is first deployed.

Prerequisites

- Install podman if it is not already installed.
- The virtual machine image must be either QCOW2 or RAW format.

Procedure

1. Create a Dockerfile to build the virtual machine image into a container image. The virtual machine image must be owned by QEMU, which has a UID of 107, and placed in the /disk/ directory inside the container. Permissions for the /disk/ directory must then be set to 0440. The following example uses the Red Hat Universal Base Image (UBI) to handle these configuration changes in the first stage, and uses the minimal scratch image in the second stage to store the result:

   $ cat > Dockerfile << EOF
   FROM registry.access.redhat.com/ubi8/ubi:latest AS builder
   EOF
Where `<vm_image>` is the virtual machine image in either QCOW2 or RAW format. To use a remote virtual machine image, replace `<vm_image>.qcow2` with the complete url for the remote image.

2. Build and tag the container:

   ```bash
   $ podman build -t <registry>/<container_disk_name>:latest .
   ``

3. Push the container image to the registry:

   ```bash
   $ podman push <registry>/<container_disk_name>:latest
   ``

If your container registry does not have TLS you must add it as an insecure registry before you can import container disks into persistent storage.

8.19.17.3. Disabling TLS for a container registry to use as insecure registry

You can disable TLS (transport layer security) for one or more container registries by editing the `insecureRegistries` field of the `HyperConverged` custom resource.

Prerequisites

- Log in to the cluster as a user with the `cluster-admin` role.

Procedure

- Edit the `HyperConverged` custom resource and add a list of insecure registries to the `spec.storageImport.insecureRegistries` field.

```yaml
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  storageImport:
    insecureRegistries:
      - "private-registry-example-1:5000"
      - "private-registry-example-2:5000"
```

Replace the examples in this list with valid registry hostnames.

8.19.17.4. Next steps

- Import the container disk into persistent storage for a virtual machine.
• Create a virtual machine that uses a `containerDisk` volume for ephemeral storage.

8.19.18. Preparing CDI scratch space

8.19.18.1. About data volumes

**DataVolume** objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.19.18.2. About scratch space

The Containerized Data Importer (CDI) requires scratch space (temporary storage) to complete some operations, such as importing and uploading virtual machine images. During this process, CDI provisions a scratch space PVC equal to the size of the PVC backing the destination data volume (DV). The scratch space PVC is deleted after the operation completes or aborts.

You can define the storage class that is used to bind the scratch space PVC in the `spec.scratchSpaceStorageClass` field of the `HyperConverged` custom resource.

If the defined storage class does not match a storage class in the cluster, then the default storage class defined for the cluster is used. If there is no default storage class defined in the cluster, the storage class used to provision the original DV or PVC is used.

**NOTE**

CDI requires requesting scratch space with a `file` volume mode, regardless of the PVC backing the origin data volume. If the origin PVC is backed by `block` volume mode, you must define a storage class capable of provisioning `file` volume mode PVCs.

**Manual provisioning**

If there are no storage classes, CDI uses any PVCs in the project that match the size requirements for the image. If there are no PVCs that match these requirements, the CDI import pod remains in a `Pending` state until an appropriate PVC is made available or until a timeout function kills the pod.

8.19.18.3. CDI operations that require scratch space

<table>
<thead>
<tr>
<th>Type</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registry imports</td>
<td>CDI must download the image to a scratch space and extract the layers to find the image file. The image file is then passed to QEMU-IMG for conversion to a raw disk.</td>
</tr>
<tr>
<td>Upload image</td>
<td>QEMU-IMG does not accept input from STDIN. Instead, the image to upload is saved in scratch space before it can be passed to QEMU-IMG for conversion.</td>
</tr>
</tbody>
</table>
### HTTP imports of archived images

QEMU-IMG does not know how to handle the archive formats CDI supports. Instead, the image is unarchived and saved into scratch space before it is passed to QEMU-IMG.

### HTTP imports of authenticated images

QEMU-IMG inadequately handles authentication. Instead, the image is saved to scratch space and authenticated before it is passed to QEMU-IMG.

### HTTP imports of custom certificates

QEMU-IMG inadequately handles custom certificates of HTTPS endpoints. Instead, CDI downloads the image to scratch space before passing the file to QEMU-IMG.

#### 8.19.18.4. Defining a storage class

You can define the storage class that the Containerized Data Importer (CDI) uses when allocating scratch space by adding the `spec.scratchSpaceStorageClass` field to the `HyperConverged` custom resource (CR).

**Prerequisites**

- Install the OpenShift CLI (`oc`).

**Procedure**

1. Edit the `HyperConverged` CR by running the following command:

   ```bash
   $ oc edit hco -n openshift-cnv kubevirt-hyperconverged
   ```

2. Add the `spec.scratchSpaceStorageClass` field to the CR, setting the value to the name of a storage class that exists in the cluster:

   ```yaml
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
   spec:
     scratchSpaceStorageClass: "<storage_class>" 1
   ```

   1 If you do not specify a storage class, CDI uses the storage class of the persistent volume claim that is being populated.

3. Save and exit your default editor to update the `HyperConverged` CR.

#### 8.19.18.5. CDI supported operations matrix
This matrix shows the supported CDI operations for content types against endpoints, and which of these operations requires scratch space.

<table>
<thead>
<tr>
<th>Content types</th>
<th>HTTP</th>
<th>HTTPS</th>
<th>HTTP basic auth</th>
<th>Registry</th>
<th>Upload</th>
</tr>
</thead>
<tbody>
<tr>
<td>KubeVirt (QCOW2)</td>
<td>✓ QCOW2</td>
<td>✓ QCOW2**</td>
<td>✓ QCOW2</td>
<td>✓ QCOW2*</td>
<td>✓ QCOW2*</td>
</tr>
<tr>
<td></td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>✓ GZ*</td>
<td>□ GZ</td>
<td>✓ GZ*</td>
</tr>
<tr>
<td></td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>✓ XZ*</td>
<td>□ XZ</td>
<td>✓ XZ*</td>
</tr>
<tr>
<td>KubeVirt (RAW)</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW</td>
<td>✓ RAW*</td>
<td>✓ RAW*</td>
</tr>
<tr>
<td></td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>✓ GZ</td>
<td>□ GZ</td>
<td>✓ GZ*</td>
</tr>
<tr>
<td></td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>✓ XZ</td>
<td>□ XZ</td>
<td>✓ XZ*</td>
</tr>
</tbody>
</table>

✓ Supported operation

□ Unsupported operation

* Requires scratch space

** Requires scratch space if a custom certificate authority is required

8.19.18.6. Additional resources

- Dynamic provisioning

8.19.19. Re-using persistent volumes

To re-use a statically provisioned persistent volume (PV), you must first reclaim the volume. This involves deleting the PV so that the storage configuration can be re-used.

8.19.19.1. About reclaiming statically provisioned persistent volumes

When you reclaim a persistent volume (PV), you unbind the PV from a persistent volume claim (PVC) and delete the PV. Depending on the underlying storage, you might need to manually delete the shared storage.

You can then re-use the PV configuration to create a PV with a different name.

Statically provisioned PVs must have a reclaim policy of Retain to be reclaimed. If they do not, the PV enters a failed state when the PVC is unbound from the PV.

**IMPORTANT**

The Recycle reclaim policy is deprecated in OpenShift Container Platform 4.

8.19.19.2. Reclaiming statically provisioned persistent volumes

Reclaim a statically provisioned persistent volume (PV) by unbinding the persistent volume claim (PVC) and deleting the PV. You might also need to manually delete the shared storage.

Reclaiming a statically provisioned PV is dependent on the underlying storage. This procedure provides a general approach that might need to be customized depending on your storage.
OpenShift Container Platform 4.10 Virtualization

Procedure
1. Ensure that the reclaim policy of the PV is set to Retain:
a. Check the reclaim policy of the PV:
$ oc get pv <pv_name> -o yaml | grep 'persistentVolumeReclaimPolicy'
b. If the persistentVolumeReclaimPolicy is not set to Retain, edit the reclaim policy with the
following command:
$ oc patch pv <pv_name> -p '{"spec":{"persistentVolumeReclaimPolicy":"Retain"}}'
2. Ensure that no resources are using the PV:
$ oc describe pvc <pvc_name> | grep 'Mounted By:'
Remove any resources that use the PVC before continuing.
3. Delete the PVC to release the PV:
$ oc delete pvc <pvc_name>
4. Optional: Export the PV configuration to a YAML file. If you manually remove the shared storage
later in this procedure, you can refer to this configuration. You can also use spec parameters in
this file as the basis to create a new PV with the same storage configuration after you reclaim
the PV:
$ oc get pv <pv_name> -o yaml > <file_name>.yaml
5. Delete the PV:
$ oc delete pv <pv_name>
6. Optional: Depending on the storage type, you might need to remove the contents of the shared
storage folder:
$ rm -rf <path_to_share_storage>
7. Optional: Create a PV that uses the same storage configuration as the deleted PV. If you
exported the reclaimed PV configuration earlier, you can use the spec parameters of that file as
the basis for a new PV manifest:

NOTE
To avoid possible conflict, it is good practice to give the new PV object a
different name than the one that you deleted.
$ oc create -f <new_pv_name>.yaml
Additional resources

252


● Configuring local storage for virtual machines

● The OpenShift Container Platform Storage documentation has more information on Persistent Storage.

8.19.20. Expanding a virtual machine disk

You can enlarge the size of a virtual machine’s (VM) disk to provide a greater storage capacity by resizing the disk’s persistent volume claim (PVC).

However, you cannot reduce the size of a VM disk.

8.19.20.1. Enlarging a virtual machine disk

VM disk enlargement makes extra space available to the virtual machine. However, it is the responsibility of the VM owner to decide how to consume the storage.

If the disk is a Filesystem PVC, the matching file expands to the remaining size while reserving some space for file system overhead.

Procedure

1. Edit the PersistentVolumeClaim manifest of the VM disk that you want to expand:

```bash
$ oc edit pvc <pvc_name>
```

2. Change the value of `spec.resource.requests.storage` attribute to a larger size.

```yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: vm-disk-expand
spec:
  accessModes:
    - ReadWriteMany
  resources:
    requests:
      storage: 3Gi
...  # 1
```

1. The VM disk size that can be increased

8.19.20.2. Additional resources

- Extending a basic volume in Windows.
- Extending an existing file system partition without destroying data in Red Hat Enterprise Linux.
- Extending a logical volume and its file system online in Red Hat Enterprise Linux.

8.19.21. Deleting data volumes

You can manually delete a data volume by using the `oc` command-line interface.
NOTE
When you delete a virtual machine, the data volume it uses is automatically deleted.

8.19.21.1. About data volumes

DataVolume objects are custom resources that are provided by the Containerized Data Importer (CDI) project. Data volumes orchestrate import, clone, and upload operations that are associated with an underlying persistent volume claim (PVC). Data volumes are integrated with OpenShift Virtualization, and they prevent a virtual machine from being started before the PVC has been prepared.

8.19.21.2. Listing all data volumes

You can list the data volumes in your cluster by using the `oc` command-line interface.

Procedure

- List all data volumes by running the following command:

  ```
  $ oc get dvs
  ```

8.19.21.3. Deleting a data volume

You can delete a data volume by using the `oc` command-line interface (CLI).

Prerequisites

- Identify the name of the data volume that you want to delete.

Procedure

- Delete the data volume by running the following command:

  ```
  $ oc delete dv <datavolume_name>
  ```

NOTE
This command only deletes objects that exist in the current project. Specify the `-n <project_name>` option if the object you want to delete is in a different project or namespace.
CHAPTER 9. VIRTUAL MACHINE TEMPLATES

9.1. CREATING VIRTUAL MACHINE TEMPLATES

9.1.1. About virtual machine templates

Preconfigured Red Hat virtual machine templates are listed in the Templates tab within the Virtualization page. These templates are available for different versions of Red Hat Enterprise Linux, Fedora, Microsoft Windows 10, and Microsoft Windows Servers. Each Red Hat virtual machine template is preconfigured with the operating system image, default settings for the operating system, flavor (CPU and memory), and workload type (server).

The Templates tab displays four types of virtual machine templates:

- **Red Hat Supported** templates are fully supported by Red Hat.
- **User Supported** templates are **Red Hat Supported** templates that were cloned and created by users.
- **Red Hat Provided** templates have limited support from Red Hat.
- **User Provided** templates are **Red Hat Provided** templates that were cloned and created by users.

**NOTE**

In the Templates tab, you cannot edit or delete Red Hat Supported or Red Hat Provided templates. You can only edit or delete custom virtual machine templates that were created by users.

Using a Red Hat template is convenient because the template is already preconfigured. When you select a Red Hat template to create your own custom template, the Create Virtual Machine Template wizard prompts you to add a boot source if a boot source was not added previously. Then, you can either save your custom template or continue to customize it and save it.

You can also select the Create Virtual Machine Template wizard directly and create a custom virtual machine template. The wizard prompts you to provide configuration details for the operating system, flavor, workload type, and other settings. You can add a boot source and continue to customize your template and save it.

**IMPORTANT**

Due to differences in storage behavior, some virtual machine templates are incompatible with SNO. To ensure compatibility, do not set the evictionStrategy field for any templates or virtual machines that use data volumes or storage profiles.

9.1.2. About virtual machines and boot sources

Virtual machines consist of a virtual machine definition and one or more disks that are backed by data volumes. Virtual machine templates enable you to create virtual machines using predefined virtual machine specifications.

Every virtual machine template requires a boot source, which is a fully configured virtual machine disk.
image including configured drivers. Each virtual machine template contains a virtual machine definition with a pointer to the boot source. Each boot source has a predefined name and namespace. For some operating systems, a boot source is automatically provided. If it is not provided, then an administrator must prepare a custom boot source.

Provided boot sources are updated automatically to the latest version of the operating system. For auto-updated boot sources, persistent volume claims (PVCs) are created with the cluster’s default storage class. If you select a different default storage class after configuration, you must delete the existing data volumes in the cluster namespace that are configured with the previous default storage class.

To use the boot sources feature, install the latest release of OpenShift Virtualization. The namespace openshift-virtualization-os-images enables the feature and is installed with the OpenShift Virtualization Operator. Once the boot source feature is installed, you can create boot sources, attach them to templates, and create virtual machines from the templates.

Define a boot source by using a persistent volume claim (PVC) that is populated by uploading a local file, cloning an existing PVC, importing from a registry, or by URL. Attach a boot source to a virtual machine template by using the web console. After the boot source is attached to a virtual machine template, you create any number of fully configured ready-to-use virtual machines from the template.

9.1.3. Adding a boot source for a virtual machine template

A boot source can be configured for any virtual machine template that you want to use for creating virtual machines or custom templates. When virtual machine templates are configured with a boot source, they are labeled Available in the Templates tab. After you add a boot source to a template, you can create a new virtual machine from the template.

There are four methods for selecting and adding a boot source in the web console:

- Upload local file (creates PVC)
- Import via URL (creates PVC)
- Clone existing PVC (creates PVC)
- Import via Registry (creates PVC)

Prerequisites

- To add a boot source, you must be logged in as a user with the os-images.kubevirt.io:edit RBAC role or as an administrator. You do not need special privileges to create a virtual machine from a template with a boot source added.
- To upload a local file, the operating system image file must exist on your local machine.
- To import via URL, access to the web server with the operating system image is required. For example: the Red Hat Enterprise Linux web page with images.
- To clone an existing PVC, access to the project with a PVC is required.
- To import via registry, access to the container registry is required.

Procedure

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.
2. Click the Templates tab.

3. Identify the virtual machine template for which you want to configure a boot source and click Add source.

4. In the Add boot source to template window, click Select boot source, select a method for creating a persistent volume claim (PVC): Upload local file, Import via URL, Clone existing PVC, or Import via Registry.

5. Optional: Click This is a CD-ROM boot source to mount a CD-ROM and use it to install the operating system on to an empty disk. The additional empty disk is automatically created and mounted by OpenShift Virtualization. If the additional disk is not needed, you can remove it when you create the virtual machine.

6. Enter a value for Persistent Volume Claim size to specify the PVC size that is adequate for the uncompressed image and any additional space that is required.
   a. Optional: Enter a name for Source provider to associate the name with this template.
   b. Optional: Advanced Storage settings: Click Storage class and select the storage class that is used to create the disk. Typically, this storage class is the default storage class that is created for use by all PVCs.

   NOTE
   Provided boot sources are updated automatically to the latest version of the operating system. For auto-updated boot sources, persistent volume claims (PVCs) are created with the cluster’s default storage class. If you select a different default storage class after configuration, you must delete the existing data volumes in the cluster namespace that are configured with the previous default storage class.

   c. Optional: Advanced Storage settings: Click Access mode and select an access mode for the persistent volume:
      - Single User (RWO) mounts the volume as read-write by a single node.
      - Shared Access (RWX) mounts the volume as read-write by many nodes.
      - Read Only (ROX) mounts the volume as read-only by many nodes.

   d. Optional: Advanced Storage settings: Click Volume mode if you want to select Block instead of the default value Filesystem. OpenShift Virtualization can statically provision raw block volumes. These volumes do not have a file system, and can provide performance benefits for applications that either write to the disk directly or implement their own storage service.

7. Select the appropriate method to save your boot source:
   a. Click Save and upload if you uploaded a local file.
   b. Click Save and import if you imported content from a URL or the registry.
   c. Click Save and clone if you cloned an existing PVC.

Your custom virtual machine template with a boot source is listed in the Templates tab, and you can create virtual machines by using this template.
## 9.1.3.1. Virtual machine template fields for adding a boot source

The following table describes the fields for the **Add boot source to template** window. This window displays when you click **Add Source** for a virtual machine template in the **Templates** tab.

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boot source type</strong></td>
<td>Upload local file (creates PVC)</td>
<td>Upload a file from your local device. Supported file types include gz, xz, tar, and qcow2.</td>
</tr>
<tr>
<td></td>
<td>Import via URL (creates PVC)</td>
<td>Import content from an image available from an HTTP or S3 endpoint. Obtain the download link URL from the web page where the image download is available and enter that URL link in the <strong>Import via URL (creates PVC)</strong> field. Example: For a Red Hat Enterprise Linux image, log on to the Red Hat Customer Portal, access the image download page, and copy the download link URL for the KVM guest image.</td>
</tr>
<tr>
<td></td>
<td>Clone existing PVC (creates PVC)</td>
<td>Use a PVC that is already available in the cluster and clone it.</td>
</tr>
<tr>
<td></td>
<td>Import via Registry (creates PVC)</td>
<td>Specify the bootable operating system container that is located in a registry and accessible from the cluster. Example: kubevirt/cirros-registry-dis-demo.</td>
</tr>
<tr>
<td><strong>Source provider</strong></td>
<td></td>
<td>Optional field. Add descriptive text about the source for the template or the name of the user who created the template. Example: Red Hat.</td>
</tr>
<tr>
<td><strong>Advanced</strong></td>
<td>Storage class</td>
<td>The storage class that is used to create the disk.</td>
</tr>
<tr>
<td></td>
<td>Access mode</td>
<td>Access mode of the persistent volume. Supported access modes are <strong>Single User (RWO)</strong>, <strong>Shared Access (RWX)</strong>, <strong>Read Only (ROX)</strong>. If Single User (RWO) is selected, the disk can be mounted as read/write by a single node. If Shared Access (RWX) is selected, the disk can be mounted as read-write by many nodes. The <strong>kubevirt-storage-class-defaults</strong> config map provides access mode defaults for data volumes. The default value is set according to the best option for each storage class in the cluster.</td>
</tr>
</tbody>
</table>

**NOTE**

Shared Access (RWX) is required for some features, such as live migration of virtual machines between nodes.
### 9.1.4. Marking virtual machine templates as favorites

For easier access to virtual machine templates that are used frequently, you can mark those templates as favorites.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.
2. Click the **Templates** tab.
3. Identify the Red Hat template that you want to mark as a favorite.
4. Click the Options menu and select **Favorite template**. The template moves up higher in the list of displayed templates.

### 9.1.5. Filtering the list of virtual machine templates by providers

In the **Templates** tab, you can use the **Search by name** field to search for virtual machine templates by specifying either the name of the template or a label that identifies the template. You can also filter templates by the provider, and display only those templates that meet your filtering criteria.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.
2. Click the **Templates** tab.
3. To filter templates, click **Filter**.
4. Select the appropriate checkbox from the list to filter the templates: **Red Hat Supported**, **User Supported**, **Red Hat Provided**, and **User Provided**.

### 9.1.6. Creating a virtual machine template with the wizard in the web console

The web console features the **Create Virtual Machine Template** wizard that guides you through the **General**, **Networking**, **Storage**, **Advanced**, and **Review** steps to simplify the process of creating virtual machine templates. All required fields are marked with a *. The **Create Virtual Machine Template** wizard prevents you from moving to the next step until you provide values in the required fields.
NOTE
The wizard guides you to create a custom virtual machine template where you specify the operating system, boot source, flavor, and other settings.

Procedure

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.

2. Click the **Templates** tab.

3. Click **Create** and select **Template with Wizard**

4. Fill in all required fields in the **General** step.

5. Click **Next** to progress to the **Networking** step. A NIC that is named **nic0** is attached by default.
   
   a. Optional: Click **Add Network Interface** to create additional NICs.
   
   b. Optional: You can remove any or all NICs by clicking the Options menu **Delete**. Virtual machines created from a template do not need a NIC attached. NICs can be created after a virtual machine has been created.

6. Click **Next** to progress to the **Storage** step.

7. Click **Add Disk** to add a disk, and complete your selections for the fields in the **Add Disk** screen.

   **NOTE**

   If **Import via URL (creates PVC)**, **Import via Registry (creates PVC)**, or **Container (ephemeral)** is selected as **Source**, a **rootdisk** disk is created and attached to the virtual machine as the **Bootable Disk**.

   A **Bootable Disk** is not required for virtual machines provisioned from a **PXE** source if there are no disks attached to the virtual machine. If one or more disks are attached to the virtual machine, you must select one as the **Bootable Disk**. Blank disks, PVC disks without a valid boot source, and the cloudinitdisk cannot be used as a boot source.

8. Optional: Click **Advanced** to configure cloud-init and SSH access.

   **NOTE**

   Statically inject an SSH key by using the custom script in cloud-init or in the wizard. This allows you to securely and remotely manage virtual machines and manage and transfer information. This step is strongly recommended to secure your VM.

9. Click **Review** to review and confirm your settings.

10. Click **Create Virtual Machine template**

11. Click **See virtual machine template details** to view details about the virtual machine template.
The template is also listed in the **Templates** tab.

### 9.1.7. Virtual machine template wizard fields

The following tables describe the fields for the **General**, **Networking**, **Storage**, and **Advanced** steps in the **Create Virtual Machine Template** wizard.

#### 9.1.7.1. Virtual machine template wizard fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Template</td>
<td></td>
<td>Template from which to create the virtual machine. Selecting a template will automatically complete other fields.</td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td>The name can contain lowercase letters (a-z), numbers (0-9), and hyphens (-), up to a maximum of 253 characters. The first and last characters must be alphanumeric. The name must not contain uppercase letters, spaces, periods (.), or special characters.</td>
</tr>
<tr>
<td>Template provider</td>
<td></td>
<td>The name of the user who is creating the template for the cluster or any meaningful name that identifies this template.</td>
</tr>
<tr>
<td>Template support</td>
<td>No additional support</td>
<td>This template does not have additional support in the cluster.</td>
</tr>
<tr>
<td>Support by template provider</td>
<td></td>
<td>This template is supported by the template provider.</td>
</tr>
<tr>
<td>Description</td>
<td></td>
<td>Optional description field.</td>
</tr>
<tr>
<td>Operating System</td>
<td></td>
<td>The operating system that is selected for the virtual machine. Selecting an operating system automatically selects the default <strong>Flavor</strong> and <strong>Workload Type</strong> for that operating system.</td>
</tr>
<tr>
<td>Boot Source</td>
<td>Import via URL (creates PVC)</td>
<td>Import content from an image available from an <strong>HTTP</strong> or <strong>S3</strong> endpoint. Example: Obtaining a URL link from the web page with the operating system image.</td>
</tr>
<tr>
<td>Name</td>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>Clone existing PVC (creates PVC)</td>
<td>Select an existent persistent volume claim available on the cluster and clone it.</td>
<td></td>
</tr>
<tr>
<td>Import via Registry (creates PVC)</td>
<td>Provision virtual machine from a bootable operating system container located in a registry accessible from the cluster. Example: <code>kubevirt/cirros-registry-disk-demo</code>.</td>
<td></td>
</tr>
<tr>
<td>PXE (network boot – adds network interface)</td>
<td>Boot an operating system from a server on the network. Requires a PXE bootable network attachment definition.</td>
<td></td>
</tr>
</tbody>
</table>

| Persistent Volume Claim project | Project name that you want to use for cloning the PVC. |
| Persistent Volume Claim name | PVC name that should apply to this virtual machine template if you are cloning an existing PVC. |
| Mount this as a CD-ROM boot source | A CD-ROM requires an additional disk for installing the operating system. Select the checkbox to add a disk and customize it later. |
| Flavor | Tiny, Small, Medium, Large, Custom |

Presets the amount of CPU and memory in a virtual machine template with predefined values that are allocated to the virtual machine, depending on the operating system associated with that template.

If you choose a default template, you can override the `cpus` and `memsize` values in the template using custom values to create a custom template. Alternatively, you can create a custom template by modifying the `cpus` and `memsize` values in the Details tab on the Workloads → Virtualization page.
### Workload Type

**NOTE**

If you choose the incorrect **Workload Type**, there could be performance or resource utilization issues (such as a slow UI).

<table>
<thead>
<tr>
<th>Workload Type</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop</td>
<td>Desktop</td>
<td>A virtual machine configuration for use on a desktop. Ideal for consumption on a small scale. Recommended for use with the web console. Use this template class or the Server template class to prioritize VM density over <strong>guaranteed</strong> VM performance.</td>
</tr>
<tr>
<td>Server</td>
<td>Server</td>
<td>Balances performance and it is compatible with a wide range of server workloads. Use this template class or the Desktop template class to prioritize VM density over <strong>guaranteed</strong> VM performance.</td>
</tr>
<tr>
<td>High-Performance (requires CPU Manager)</td>
<td>High-Performance (requires CPU Manager)</td>
<td>A virtual machine configuration that is optimized for high-performance workloads. Use this template class to prioritize <strong>guaranteed</strong> VM performance over VM density.</td>
</tr>
</tbody>
</table>

#### 9.1.7.2. Networking fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name for the network interface controller.</td>
</tr>
<tr>
<td>Model</td>
<td>Indicates the model of the network interface controller. Supported values are e1000e and virtio.</td>
</tr>
<tr>
<td>Network</td>
<td>List of available network attachment definitions.</td>
</tr>
<tr>
<td>Type</td>
<td>List of available binding methods. For the default pod network, masquerade is the only recommended binding method. For secondary networks, use the bridge binding method. The masquerade method is not supported for non-default networks. Select SR-IOV if you configured an SR-IOV network device and defined that network in the namespace.</td>
</tr>
<tr>
<td>MAC Address</td>
<td>MAC address for the network interface controller. If a MAC address is not specified, one is assigned automatically.</td>
</tr>
</tbody>
</table>
### 9.1.7.3. Storage fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Selection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Blank (creates PVC)</td>
<td>Create an empty disk.</td>
</tr>
<tr>
<td></td>
<td>Import via URL (creates PVC)</td>
<td>Import content via URL (HTTP or S3 endpoint).</td>
</tr>
<tr>
<td></td>
<td>Use an existing PVC</td>
<td>Use a PVC that is already available in the cluster.</td>
</tr>
<tr>
<td></td>
<td>Clone existing PVC (creates PVC)</td>
<td>Select an existing PVC available in the cluster and clone it.</td>
</tr>
<tr>
<td></td>
<td>Import via Registry (creates PVC)</td>
<td>Import content via container registry.</td>
</tr>
<tr>
<td></td>
<td>Container (ephemeral)</td>
<td>Upload content from a container located in a registry accessible from the cluster. The container disk should be used only for read-only filesystems such as CD-ROMs or temporary virtual machines.</td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td>Name of the disk. The name can contain lowercase letters (a-z), numbers (0-9), hyphens (-), and periods (.), up to a maximum of 253 characters. The first and last characters must be alphanumeric. The name must not contain uppercase letters, spaces, or special characters.</td>
</tr>
<tr>
<td>Size</td>
<td></td>
<td>Size of the disk in GiB.</td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td>Type of disk. Example: Disk or CD-ROM</td>
</tr>
<tr>
<td>Interface</td>
<td></td>
<td>Type of disk device. Supported interfaces are virtIO, SATA, and SCSI.</td>
</tr>
<tr>
<td>Storage Class</td>
<td></td>
<td>The storage class that is used to create the disk.</td>
</tr>
</tbody>
</table>
### Advanced storage settings

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Mode</td>
<td>Filesystem</td>
<td>Stores the virtual disk on a file system-based volume.</td>
</tr>
<tr>
<td></td>
<td>Block</td>
<td>Stores the virtual disk directly on the block volume. Only use Block if the underlying storage supports it.</td>
</tr>
</tbody>
</table>

**NOTE**

Default values are used from the storage profile.

### 9.1.7.4. Cloud-init fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hostname</td>
<td>Sets a specific hostname for the virtual machine.</td>
</tr>
<tr>
<td>Authorized SSH Keys</td>
<td>The user’s public key that is copied to ~/.ssh/authorized_keys on the virtual machine.</td>
</tr>
<tr>
<td>Custom script</td>
<td>Replaces other options with a field in which you paste a custom cloud-init script.</td>
</tr>
</tbody>
</table>

### 9.1.8. Additional resources

- Configuring the SR-IOV Network Operator
- Creating and using boot sources
- Customizing the storage profile

### 9.2. EDITING VIRTUAL MACHINE TEMPLATES

You can update a virtual machine template in the web console, either by editing the full configuration in the YAML editor or by selecting a custom template in the Templates tab and modifying the editable items.
9.2.1. Editing a virtual machine template in the web console

Edit select values of a virtual machine template in the web console by clicking the pencil icon next to the relevant field. Other values can be edited using the CLI.

Labels and annotations are editable for both preconfigured Red Hat templates and your custom virtual machine templates. All other values are editable only for custom virtual machine templates that users have created using the Red Hat templates or the Create Virtual Machine Template wizard.

Procedure

1. Click Workloads → Virtualization from the side menu.
2. Click the Templates tab.
3. Select a virtual machine template.
4. Click the VM Template Details tab.
5. Click the pencil icon to make a field editable.
6. Make the relevant changes and click Save.

Editing a virtual machine template will not affect virtual machines already created from that template.

9.2.2. Editing virtual machine template YAML configuration in the web console

You can edit the YAML configuration of a virtual machine template from the web console.

Some parameters cannot be modified. If you click Save with an invalid configuration, an error message indicates the parameter that cannot be modified.

NOTE

Navigating away from the YAML screen while editing cancels any changes to the configuration that you made.

Procedure

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.
2. Click the Templates tab.
3. Select a template to open the VM Template Details screen.
4. Click the YAML tab to display the editable configuration.
5. Edit the file and click Save.

A confirmation message, which includes the updated version number for the object, shows that the YAML configuration was successfully edited.

9.2.3. Adding a virtual disk to a virtual machine template

Use this procedure to add a virtual disk to a virtual machine template.
Procedure

1. Click **Workloads → Virtualization** from the side menu.
2. Click the **Templates** tab.
3. Select a virtual machine template to open the **VM Template Details** screen.
4. Click the **Disks** tab.
5. In the **Add Disk** window, specify the **Source**, **Name**, **Size**, **Type**, **Interface**, and **Storage Class**.
   a. Advanced: You can enable preallocation if you use a blank disk source and require maximum write performance when creating data volumes. To do so, select the **Enable preallocation** checkbox.
   b. Optional: In the **Advanced** list, specify the **Volume Mode** and **Access Mode** for the virtual disk. If you do not specify these parameters, the system uses the default values from the **kubevirt-storage-class-defaults** config map.
6. Click **Add**.

9.2.4. Adding a network interface to a virtual machine template

Use this procedure to add a network interface to a virtual machine template.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.
2. Click the **Templates** tab.
3. Select a virtual machine template to open the **VM Template Details** screen.
4. Click the **Network Interfaces** tab.
5. Click **Add Network Interface**.
6. In the **Add Network Interface** window, specify the **Name**, **Model**, **Network**, **Type**, and **MAC Address** of the network interface.
7. Click **Add**.

9.2.5. Editing CD-ROMs for Templates

Use the following procedure to edit CD-ROMs for virtual machine templates.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.
2. Click the **Templates** tab.
3. Select a virtual machine template to open the **VM Template Details** screen.
4. Click the **Disks** tab.
5. Click the Options menu for the CD-ROM that you want to edit and select **Edit**.

6. In the **Edit CD-ROM** window, edit the fields: **Source**, **Persistent Volume Claim **Name**, **Type**, and **Interface**.

7. Click **Save**.

### 9.3. ENABLING DEDICATED RESOURCES FOR VIRTUAL MACHINE TEMPLATES

Virtual machines can have resources of a node, such as CPU, dedicated to them to improve performance.

#### 9.3.1. About dedicated resources

When you enable dedicated resources for your virtual machine, your virtual machine's workload is scheduled on CPUs that will not be used by other processes. By using dedicated resources, you can improve the performance of the virtual machine and the accuracy of latency predictions.

#### 9.3.2. Prerequisites

- The **CPU Manager** must be configured on the node. Verify that the node has the `cpumanager = true` label before scheduling virtual machine workloads.

#### 9.3.3. Enabling dedicated resources for a virtual machine template

You can enable dedicated resources for a virtual machine template in the **Details** tab. Virtual machines that were created by using a Red Hat template or the wizard can be enabled with dedicated resources.

**Procedure**

1. Click **Workloads** → **Virtual Machine Templates** from the side menu.

2. Select a virtual machine template to open the **Virtual Machine Template** tab.

3. Click the **Details** tab.

4. Click the pencil icon to the right of the **Dedicated Resources** field to open the **Dedicated Resources** window.

5. Select **Schedule this workload with dedicated resources (guaranteed policy)**

6. Click **Save**.

### 9.4. DEPLOYING A VIRTUAL MACHINE TEMPLATE TO A CUSTOM NAMESPACE

Red Hat provides preconfigured virtual machine templates that are installed in the **openshift** namespace. The **ssp-operator** deploys virtual machine templates to the **openshift** namespace by default. Templates in the **openshift** namespace are publicly available to all users. These templates are listed in the **Templates** tab within the **Virtualization** page for different operating systems.
9.4.1. Creating a custom namespace for templates

You can create a custom namespace that is used to deploy virtual machine templates for use by anyone who has permissions to access those templates. To add templates to a custom namespace, edit the **HyperConverged** custom resource (CR), add **commonTemplatesNamespace** to the spec, and specify the custom namespace for the virtual machine templates. After the **HyperConverged** CR is modified, the **ssp-operator** populates the templates in the custom namespace.

**Prerequisites**
- Install the OpenShift Container Platform CLI **oc**.
- Log in as a user with cluster-admin privileges.

**Procedure**
- Use the following command to create your custom namespace:

  ```
  $ oc create namespace <mycustomnamespace>
  ```

9.4.2. Adding templates to a custom namespace

The **ssp-operator** deploys virtual machine templates to the **openshift** namespace by default. Templates in the **openshift** namespace are publicly available to all users. When a custom namespace is created and templates are added to that namespace, you can modify or delete virtual machine templates in the **openshift** namespace. To add templates to a custom namespace, edit the **HyperConverged** custom resource (CR) which contains the **ssp-operator**.

**Procedure**
1. View the list of virtual machine templates that are available in the **openshift** namespace.
   ```
   $ oc get templates -n openshift
   ```
2. Edit the **HyperConverged** CR in your default editor by running the following command:
   ```
   $ oc edit hco -n openshift-cnv kubevirt-hyperconverged
   ```
3. View the list of virtual machine templates that are available in the custom namespace.
   ```
   $ oc get templates -n customnamespace
   ```
4. Add the **commonTemplatesNamespace** attribute and specify the custom namespace. Example:

```yaml
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
spec:
  commonTemplatesNamespace: customnamespace

1 The custom namespace for deploying templates.
```
5. Save your changes and exit the editor. The **ssp-operator** adds virtual machine templates that exist in the default **openshift** namespace to the custom namespace.

### 9.4.2.1. Deleting templates from a custom namespace

To delete virtual machine templates from a custom namespace, remove the `commonTemplateNamespace` attribute from the **HyperConverged** custom resource (CR) and delete each template from that custom namespace.

**Procedure**

1. Edit the **HyperConverged** CR in your default editor by running the following command:

   ```
   $ oc edit hco -n openshift-cnv kubevirt-hyperconverged
   ```

2. Remove the `commonTemplateNamespace` attribute.

   ```
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
   spec:
     commonTemplatesNamespace: customnamespace
   ```

   The `commonTemplatesNamespace` attribute to be deleted.

3. Delete a specific template from the custom namespace that was removed.

   ```
   $ oc delete templates -n customnamespace <template_name>
   ```

**Verification**

- Verify that the template was deleted from the custom namespace.

  ```
  $ oc get templates -n customnamespace
  ```

### 9.4.2.2. Additional resources

- Creating virtual machine templates

### 9.5. DELETING A VIRTUAL MACHINE TEMPLATE

Red Hat virtual machine templates cannot be deleted. You can use the web console to delete:

- Virtual machine templates created from Red Hat templates
- Custom virtual machine templates that were created by using the **Create Virtual Machine Template** wizard.

#### 9.5.1. Deleting a virtual machine template in the web console

Deleting a virtual machine template permanently removes it from the cluster.
NOTE
You can delete virtual machine templates that were created by using a Red Hat template or the Create Virtual Machine Template wizard. Preconfigured virtual machine templates that are provided by Red Hat cannot be deleted.

Procedure

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.

2. Click the Templates tab. Select the appropriate method to delete a virtual machine template:
   - Click the Options menu of the template to delete and select Delete Template.
   - Click the template name to open the Virtual Machine Template Details screen and click Actions → Delete Template.

3. In the confirmation pop-up window, click Delete to permanently delete the template.
CHAPTER 10. LIVE MIGRATION

10.1. VIRTUAL MACHINE LIVE MIGRATION

10.1.1. About live migration

Live migration is the process of moving a running virtual machine instance (VMI) to another node in the cluster without interrupting the virtual workload or access. If a VMI uses the LiveMigrate eviction strategy, it automatically migrates when the node that the VMI runs on is placed into maintenance mode. You can also manually start live migration by selecting a VMI to migrate.

You can use live migration if the following conditions are met:

- Virtual machines must have a persistent volume claim (PVC) with a shared ReadWriteMany (RWX) access mode to be live migrated.
- The pod network binding must not be of the bridge interface type.
- Live migration is supported for virtual machines that are attached to an SR-IOV network interface.
- If the virtual machine uses a host model CPU, live migration is supported only between nodes that support the virtual machine’s host model CPU.

10.1.2. Updating access mode for live migration

For live migration to function properly, you must use the ReadWriteMany (RWX) access mode. Use this procedure to update the access mode, if needed.

Procedure

- To set the RWX access mode, run the following `oc patch` command:

  ```
  $ oc patch -n openshift-cnv \ 
  cm kubevirt-storage-class-defaults \ 
  -p '{"data":{"<STORAGE_CLASS>\.accessMode":"ReadWriteMany"}}'
  ```

Additional resources:

- Migrating a virtual machine instance to another node
- Live migration limiting
- Customizing the storage profile

10.2. LIVE MIGRATION LIMITS AND TIMEOUTS

Apply live migration limits and timeouts so that migration processes do not overwhelm the cluster. Configure these settings by editing the `HyperConverged` custom resource (CR).

10.2.1. Configuring live migration limits and timeouts
Configure live migration limits and timeouts for the cluster by updating the **HyperConverged** custom resource (CR), which is located in the **openshift-cnv** namespace.

**Procedure**

- Edit the **HyperConverged** CR and add the necessary live migration parameters.

```bash
$ oc edit hco -n openshift-cnv kubevirt-hyperconverged
```

**Example configuration file**

```yaml
apiVersion: hco.kubevirt.io/v1beta1
kind: HyperConverged
metadata:
  name: kubevirt-hyperconverged
  namespace: openshift-cnv
spec:
  liveMigrationConfig: # 1
    bandwidthPerMigration: 64Mi
    completionTimeoutPerGiB: 800
    parallelMigrationsPerCluster: 5
    parallelOutboundMigrationsPerNode: 2
    progressTimeout: 150
```

1. In this example, the **spec.liveMigrationConfig** array contains the default values for each field.

**NOTE**

You can restore the default value for any **spec.liveMigrationConfig** field by deleting that key/value pair and saving the file. For example, delete `progressTimeout: <value>` to restore the default `progressTimeout: 150`.

### 10.2.2. Cluster-wide live migration limits and timeouts

**Table 10.1. Migration parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>parallelMigrationsPerCluster</code></td>
<td>Number of migrations running in parallel in the cluster.</td>
<td>5</td>
</tr>
<tr>
<td><code>parallelOutboundMigrationsPerNode</code></td>
<td>Maximum number of outbound migrations per node.</td>
<td>2</td>
</tr>
<tr>
<td><code>bandwidthPerMigration</code></td>
<td>Bandwidth limit of each migration, in MiB/s.</td>
<td>64Mi</td>
</tr>
</tbody>
</table>
**Parameter** | **Description** | **Default**
--- | --- | ---
**completionTimeoutPerGiB** | The migration is canceled if it has not completed in this time, in seconds per GiB of memory. For example, a virtual machine instance with 6GiB memory times out if it has not completed migration in 4800 seconds. If the **Migration Method** is **BlockMigration**, the size of the migrating disks is included in the calculation. | 800

**progressTimeout** | The migration is canceled if memory copy fails to make progress in this time, in seconds. | 150

### 10.3. MIGRATING A VIRTUAL MACHINE INSTANCE TO ANOTHER NODE

Manually initiate a live migration of a virtual machine instance to another node using either the web console or the CLI.

**NOTE**

If a virtual machine uses a host model CPU, you can perform live migration of that virtual machine only between nodes that support its host CPU model.

### 10.3.1. Initiating live migration of a virtual machine instance in the web console

Migrate a running virtual machine instance to a different node in the cluster.

**NOTE**

The **Migrate Virtual Machine** action is visible to all users but only admin users can initiate a virtual machine migration.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.
2. Click the **Virtual Machines** tab.
3. You can initiate the migration from this screen, which makes it easier to perform actions on multiple virtual machines in the one screen, or from the **Virtual Machine Overview** screen where you can view comprehensive details of the selected virtual machine:
   - Click the Options menu at the end of virtual machine and select **Migrate Virtual Machine**.
   - Click the virtual machine name to open the **Virtual Machine Overview** screen and click **Actions → Migrate Virtual Machine**
4. Click **Migrate** to migrate the virtual machine to another node.
10.3.2. Initiating live migration of a virtual machine instance in the CLI

Initiate a live migration of a running virtual machine instance by creating a `VirtualMachineInstanceMigration` object in the cluster and referencing the name of the virtual machine instance.

**Procedure**

1. Create a `VirtualMachineInstanceMigration` configuration file for the virtual machine instance to migrate. For example, `vmi-migrate.yaml`:

   ```yaml
   apiVersion: kubevirt.io/v1
   kind: VirtualMachineInstanceMigration
   metadata:
     name: migration-job
   spec:
     vmiName: vmi-fedora
   
   $ oc create -f vmi-migrate.yaml
   ``

   The `VirtualMachineInstanceMigration` object triggers a live migration of the virtual machine instance. This object exists in the cluster for as long as the virtual machine instance is running, unless manually deleted.

Additional resources:

- Monitoring live migration of a virtual machine instance
- Cancelling the live migration of a virtual machine instance

10.4. MIGRATING A VIRTUAL MACHINE OVER A DEDICATED SECONDARY NETWORK

You can configure a dedicated secondary Multus network for live migration. A dedicated network minimizes disruption to tenant workloads due to network saturation when virtual machine live migration is triggered.

10.4.1. Configuring a dedicated secondary network for virtual machine live migration

To configure a dedicated secondary network for live migration, you must first create a bridge network attachment definition for a namespace by using the CLI. Then, add the name of the `NetworkAttachmentDefinition` object to the `HyperConverged` custom resource (CR).

**Prerequisites**

- You installed the OpenShift CLI (`oc`).
- You logged in to the cluster as a user with the `cluster-admin` role.
- The Multus Container Network Interface (CNI) plug-in is installed on the cluster.
Every node on the cluster has at least two Network Interface Cards (NICs), and the NICs to be used for live migration are connected to the same VLAN.

The virtual machine (VM) is running with the **LiveMigrate** eviction strategy.

**Procedure**

1. Create a **NetworkAttachmentDefinition** manifest.

   **Example configuration file**

   ```yaml
   apiVersion: "k8s.cni.cncf.io/v1"
   kind: NetworkAttachmentDefinition
   metadata:
     name: my-secondary-network
     namespace: openshift-cnv
   spec:
     config: '{
       "cniVersion": "0.3.1",
       "name": "migration-bridge",
       "type": "macvlan",
       "master": "eth1",
       "mode": "bridge",
       "ipam": {
         "type": "whereabouts",
         "range": "10.200.5.0/24"
       }
     }'
   ``

   1. The name of the **NetworkAttachmentDefinition** object.
   2. The name of the NIC to be used for live migration.
   3. The name of the CNI plug-in that provides the network for this network attachment definition.
   4. The IP address range for the secondary network. This range must not have any overlap with the IP addresses of the main network.

2. Open the **HyperConverged** CR in your default editor by running the following command:

   ```bash
   oc edit hyperconverged kubevirt-hyperconverged -n openshift-cnv
   ```

3. Add the name of the **NetworkAttachmentDefinition** object to the **spec.liveMigrationConfig** stanza of the **HyperConverged** CR. For example:

   **Example configuration file**

   ```yaml
   apiVersion: hco.kubevirt.io/v1beta1
   kind: HyperConverged
   metadata:
     name: kubevirt-hyperconverged
   spec:
     liveMigrationConfig:
   ```
The name of the Multus `NetworkAttachmentDefinition` object to be used for live migrations.

4. Save your changes and exit the editor. The `virt-handler` pods restart and connect to the secondary network.

**Verification**

- When the node that the virtual machine runs on is placed into maintenance mode, the VM automatically migrates to another node in the cluster. You can verify that the migration occurred over the secondary network and not the default pod network by checking the target IP address in the virtual machine instance (VMI) metadata.

```
oc get vmi <vmi_name> -o jsonpath='{.status.migrationState.targetNodeAddress}'
```

10.4.2. Additional resources

- **Live migration limits and timeouts**

10.5. **MONITORING LIVE MIGRATION OF A VIRTUAL MACHINE INSTANCE**

You can monitor the progress of a live migration of a virtual machine instance from either the web console or the CLI.

10.5.1. Monitoring live migration of a virtual machine instance in the web console

For the duration of the migration, the virtual machine has a status of **Migrating**. This status is displayed in the **Virtual Machines** tab or in the **Virtual Machine Overview** screen for the migrating virtual machine.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.
2. Click the **Virtual Machines** tab.
3. Select a virtual machine to open the **Virtual Machine Overview** screen.

10.5.2. Monitoring live migration of a virtual machine instance in the CLI

The status of the virtual machine migration is stored in the **Status** component of the **VirtualMachineInstance** configuration.

**Procedure**
10.6. CANCELLING THE LIVE MIGRATION OF A VIRTUAL MACHINE INSTANCE

Cancel the live migration so that the virtual machine instance remains on the original node.

You can cancel a live migration from either the web console or the CLI.

10.6.1. Cancelling live migration of a virtual machine instance in the web console

You can cancel a live migration of the virtual machine instance using the Options menu found on each virtual machine in the Virtualization → Virtual Machines tab, or from the Actions menu available on all tabs in the Virtual Machine Overview screen.

Procedure

1. In the OpenShift Virtualization console, click Workloads → Virtualization from the side menu.

2. Click the Virtual Machines tab.

3. You can cancel the migration from this screen, which makes it easier to perform actions on multiple virtual machines, or from the Virtual Machine Overview screen where you can view comprehensive details of the selected virtual machine:

   - Click the Options menu at the end of virtual machine and select Cancel Virtual Machine Migration.
4. Click Cancel Migration to cancel the virtual machine live migration.

10.6.2. Cancelling live migration of a virtual machine instance in the CLI

Cancel the live migration of a virtual machine instance by deleting the VirtualMachineInstanceMigration object associated with the migration.

Procedure

- Delete the VirtualMachineInstanceMigration object that triggered the live migration, migration-job in this example:

  $ oc delete vmim migration-job

10.7. CONFIGURING VIRTUAL MACHINE EVICTION STRATEGY

The LiveMigrate eviction strategy ensures that a virtual machine instance is not interrupted if the node is placed into maintenance or drained. Virtual machines instances with this eviction strategy will be live migrated to another node.

10.7.1. Configuring custom virtual machines with the LiveMigration eviction strategy

You only need to configure the LiveMigration eviction strategy on custom virtual machines. Common templates have this eviction strategy configured by default.

Procedure

1. Add the evictionStrategy: LiveMigrate option to the spec.template.spec section in the virtual machine configuration file. This example uses oc edit to update the relevant snippet of the VirtualMachine configuration file:

   $ oc edit vm <custom-vm> -n <my-namespace>

   apiVersion: kubevirt.io/v1
   kind: VirtualMachine
   metadata:
     name: custom-vm
   spec:
     template:
       spec:
         evictionStrategy: LiveMigrate

   ...

2. Restart the virtual machine for the update to take effect:

   $ virtctl restart <custom-vm> -n <my-namespace>
CHAPTER 11. NODE MAINTENANCE

11.1. ABOUT NODE MAINTENANCE

11.1.1. About node maintenance mode

Nodes can be placed into maintenance mode using the `oc adm` utility, or using `NodeMaintenance` custom resources (CRs).

Placing a node into maintenance marks the node as unschedulable and drains all the virtual machines and pods from it. Virtual machine instances that have a `LiveMigrate` eviction strategy are live migrated to another node without loss of service. This eviction strategy is configured by default in virtual machine created from common templates but must be configured manually for custom virtual machines.

Virtual machine instances without an eviction strategy are shut down. Virtual machines with a `RunStrategy` of `Running` or `RerunOnFailure` are recreated on another node. Virtual machines with a `RunStrategy` of `Manual` are not automatically restarted.

**IMPORTANT**

Virtual machines must have a persistent volume claim (PVC) with a shared `ReadWriteMany` (RWX) access mode to be live migrated.

When installed as part of OpenShift Virtualization, Node Maintenance Operator watches for new or deleted `NodeMaintenance` CRs. When a new `NodeMaintenance` CR is detected, no new workloads are scheduled and the node is cordoned off from the rest of the cluster. All pods that can be evicted are evicted from the node. When a `NodeMaintenance` CR is deleted, the node that is referenced in the CR is made available for new workloads.

**NOTE**

Using a `NodeMaintenance` CR for node maintenance tasks achieves the same results as the `oc adm cordon` and `oc adm drain` commands using standard OpenShift Container Platform custom resource processing.

11.1.2. Maintaining bare metal nodes

When you deploy OpenShift Container Platform on bare metal infrastructure, there are additional considerations that must be taken into account compared to deploying on cloud infrastructure. Unlike in cloud environments where the cluster nodes are considered ephemeral, re-provisioning a bare metal node requires significantly more time and effort for maintenance tasks.

When a bare metal node fails, for example, if a fatal kernel error happens or a NIC card hardware failure occurs, workloads on the failed node need to be restarted elsewhere else on the cluster while the problem node is repaired or replaced. Node maintenance mode allows cluster administrators to gracefully power down nodes, moving workloads to other parts of the cluster and ensuring workloads do not get interrupted. Detailed progress and node status details are provided during maintenance.

Additional resources:

- About RunStrategies for virtual machines
- Virtual machine live migration
Configuring virtual machine eviction strategy

11.2. SETTING A NODE TO MAINTENANCE MODE

Place a node into maintenance from the web console, CLI, or using a NodeMaintenance custom resource.

11.2.1. Setting a node to maintenance mode in the web console

Set a node to maintenance mode using the Options menu found on each node in the Compute → Nodes list, or using the Actions control of the Node Details screen.

Procedure

1. In the OpenShift Virtualization console, click Compute → Nodes.

2. You can set the node to maintenance from this screen, which makes it easier to perform actions on multiple nodes in the one screen or from the Node Details screen where you can view comprehensive details of the selected node:

   - Click the Options menu at the end of the node and select Start Maintenance.
   - Click the node name to open the Node Details screen and click Actions → Start Maintenance.

3. Click Start Maintenance in the confirmation window.

The node will live migrate virtual machine instances that have the LiveMigration eviction strategy, and the node is no longer schedulable. All other pods and virtual machines on the node are deleted and recreated on another node.

11.2.2. Setting a node to maintenance mode in the CLI

Set a node to maintenance mode by marking it as unschedulable and using the oc adm drain command to evict or delete pods from the node.

Procedure

1. Mark the node as unschedulable. The node status changes to NotReady,SchedulingDisabled.

   
   $ oc adm cordon <node1>

2. Drain the node in preparation for maintenance. The node live migrates virtual machine instances that have the LiveMigratable condition set to True and the spec:evictionStrategy field set to LiveMigrate. All other pods and virtual machines on the node are deleted and recreated on another node.

   
   $ oc adm drain <node1> --delete-local-data --ignore-daemonsets=true --force
The `--delete-local-data` flag removes any virtual machine instances on the node that use `emptyDir` volumes. Data in these volumes is ephemeral and is safe to be deleted after termination.

The `--ignore-daemonsets=true` flag ensures that daemon sets are ignored and pod eviction can continue successfully.

The `--force` flag is required to delete pods that are not managed by a replica set or daemon set controller.

### 11.2.3. Setting a node to maintenance mode with a NodeMaintenance custom resource

You can put a node into maintenance mode with a NodeMaintenance custom resource (CR). When you apply a NodeMaintenance CR, all allowed pods are evicted and the node is shut down. Evicted pods are queued to be moved to another node in the cluster.

**Prerequisites**

- Install the OpenShift Container Platform CLI `oc`.
- Log in to the cluster as a user with `cluster-admin` privileges.

**Procedure**

1. Create the following node maintenance CR, and save the file as `nodemaintenance-cr.yaml`:

```yaml
apiVersion: nodemaintenance.kubevirt.io/v1beta1
kind: NodeMaintenance
metadata:
  name: maintenance-example 1
spec:
  nodeName: node-1.example.com 2
  reason: "Node maintenance" 3
```

1. Node maintenance CR name
2. The name of the node to be put into maintenance mode
3. Plain text description of the reason for maintenance

2. Apply the node maintenance schedule by running the following command:

   ```bash
   $ oc apply -f nodemaintenance-cr.yaml
   ```

3. Check the progress of the maintenance task by running the following command, replacing `<node-name>` with the name of your node:

   ```bash
   $ oc describe node <node-name>
   ```

**Example output**

### Events:

```bash
Events:
```
11.2.3.1. Checking status of current NodeMaintenance CR tasks

You can check the status of current NodeMaintenance CR tasks.

Prerequisites

- Install the OpenShift Container Platform CLI `oc`.
- Log in as a user with `cluster-admin` privileges.

Procedure

- Check the status of current node maintenance tasks by running the following command:

  ```
  $ oc get NodeMaintenance -o yaml
  ```

Example output

```
apiVersion: v1
items:
  - apiVersion: nodemaintenance.kubevirt.io/v1beta1
    kind: NodeMaintenance
    metadata:
      spec:
        nodeName: node-1.example.com
        reason: Node maintenance
        status:
          evictionPods: 3
          pendingPods:
            - pod-example-workload-0
            - httpd
            - httpd-manual
            phase: Running
          lastError: "Last failure message"
          totalpods: 5
```

1. `evictionPods` is the number of pods scheduled for eviction.
2. `lastError` records the latest eviction error, if any.

Additional resources:

- Resuming a node from maintenance mode
- Virtual machine live migration
11.3. RESUMING A NODE FROM MAINTENANCE MODE

Resuming a node brings it out of maintenance mode and makes it schedulable again.

Resume a node from maintenance mode from the web console, CLI, or by deleting the NodeMaintenance custom resource.

11.3.1. Resuming a node from maintenance mode in the web console

Resume a node from maintenance mode using the Options menu found on each node in the Compute → Nodes list, or using the Actions control of the Node Details screen.

Procedure

1. In the OpenShift Virtualization console, click Compute → Nodes.

2. You can resume the node from this screen, which makes it easier to perform actions on multiple nodes in the one screen, or from the Node Details screen where you can view comprehensive details of the selected node:
   - Click the Options menu at the end of the node and select Stop Maintenance.
   - Click the node name to open the Node Details screen and click Actions → Stop Maintenance.

3. Click Stop Maintenance in the confirmation window.

The node becomes schedulable, but virtual machine instances that were running on the node prior to maintenance will not automatically migrate back to this node.

11.3.2. Resuming a node from maintenance mode in the CLI

Resume a node from maintenance mode by making it schedulable again.

Procedure

- Mark the node as schedulable. You can then resume scheduling new workloads on the node.

   $ oc adm uncordon <node1>

11.3.3. Resuming a node from maintenance mode that was initiated with a NodeMaintenance CR

You can resume a node by deleting the NodeMaintenance CR.

Prerequisites

- Install the OpenShift Container Platform CLI oc.
• Log in to the cluster as a user with `cluster-admin` privileges.

**Procedure**

• When your node maintenance task is complete, delete the active `NodeMaintenance` CR:

  ```
  $ oc delete -f nodemaintenance-cr.yaml
  
  Example output
  
  nodemaintenance.nodemaintenance.kubevirt.io "maintenance-example" deleted
  ```

### 11.4. AUTOMATIC RENEWAL OF TLS CERTIFICATES

All TLS certificates for OpenShift Virtualization components are renewed and rotated automatically. You are not required to refresh them manually.

#### 11.4.1. TLS certificates automatic renewal schedules

TLS certificates are automatically deleted and replaced according to the following schedule:

- KubeVirt certificates are renewed daily.
- Containerized Data Importer controller (CDI) certificates are renewed every 15 days.
- MAC pool certificates are renewed every year.

Automatic TLS certificate rotation does not disrupt any operations. For example, the following operations continue to function without any disruption:

- Migrations
- Image uploads
- VNC and console connections

### 11.5. MANAGING NODE LABELING FOR OBSOLETE CPU MODELS

You can schedule a virtual machine (VM) on a node as long as the VM CPU model and policy are supported by the node.

#### 11.5.1. About node labeling for obsolete CPU models

The OpenShift Virtualization Operator uses a predefined list of obsolete CPU models to ensure that a node supports only valid CPU models for scheduled VMs.

By default, the following CPU models are eliminated from the list of labels generated for the node:

**Example 11.1. Obsolete CPU models**

"486"  
Conroe  
athlon
This predefined list is not visible in the HyperConverged CR. You cannot remove CPU models from this list, but you can add to the list by editing the `spec.obsoleteCPUs.cpuModels` field of the HyperConverged CR.

### 11.5.2. About node labeling for CPU features

Through the process of iteration, the base CPU features in the minimum CPU model are eliminated from the list of labels generated for the node.

For example:

- An environment might have two supported CPU models: Penryn and Haswell.
- If Penryn is specified as the CPU model for `minCPU`, each base CPU feature for Penryn is compared to the list of CPU features supported by Haswell.

**Example 11.2. CPU features supported by Penryn**

```plaintext
apic
ciflush
cmov
cx16
cx8
de
tpu
fxsr
lahf_lm
lm
mca
mce
mmx
msr
mtrr
nx
pae
pat
pge
pni
pse
pse36
sep
sse
```
Example 11.3. CPU features supported by Haswell

- aes
- apic
- avx
- avx2
- bmi1
- bmi2
- clflush
- cmov
- cx16
- cx8
- de
- erms
- fma
- fpu
- fsgsbase
- fxsr
- hle
- invpcid
- lahf_lm
- lm
- mca
- mce
- mmx
- movbe
- msr
- mtrr
- nx
- pae
- pat
- pcd
- pclmulqdq
- pge
- pni
- popcnt
- pse
- pse36
- rdtscp
- rtm
- sep
- smep
- sse
- sse2
- sse4.1
- sse4.2
- ssse3
- syscall
- tsc
- syscall
- tsc
- syscall
- tsc
- syscall
- tsc
If both Penryn and Haswell support a specific CPU feature, a label is not created for that feature. Labels are generated for CPU features that are supported only by Haswell and not by Penryn.

Example 11.4. Node labels created for CPU features after iteration

```plaintext
tsc
tsc-deadline
x2apic
xsave
```

11.5.3. Configuring obsolete CPU models

You can configure a list of obsolete CPU models by editing the HyperConverged custom resource (CR).

**Procedure**

- Edit the HyperConverged custom resource, specifying the obsolete CPU models in the `obsoleteCPUs` array. For example:

```plaintext
apiVersion: hco.kubevirt.io/v1beta1
class: HyperConverged
metadata:
  name: kubevirt-hyperconverged
namespace: openshift-cn
spec:
obsoleteCPUs:
cpuModels: 1
```
Replace the example values in the `cpuModels` array with obsolete CPU models. Any value that you specify is added to a predefined list of obsolete CPU models. The predefined list is not visible in the CR.

Replace this value with the minimum CPU model that you want to use for basic CPU features. If you do not specify a value, `Penryn` is used by default.

11.6. PREVENTING NODE RECONCILIATION

Use `skip-node` annotation to prevent the `node-labeller` from reconciling a node.

11.6.1. Using skip-node annotation

If you want the `node-labeller` to skip a node, annotate that node by using the `oc` CLI.

**Prerequisites**

- You have installed the OpenShift CLI (`oc`).

**Procedure**

- Annotate the node that you want to skip by running the following command:

```
$ oc annotate node <node_name> node-labeller.kubevirt.io/skip-node=true
```

1 Replace `<node_name>` with the name of the relevant node to skip.

Reconciliation resumes on the next cycle after the node annotation is removed or set to false.

11.6.2. Additional resources

- Managing node labeling for obsolete CPU models
CHAPTER 12. NODE NETWORKING

12.1. OBSERVING NODE NETWORK STATE

Node network state is the network configuration for all nodes in the cluster.

12.1.1. About nmstate

OpenShift Virtualization uses nmstate to report on and configure the state of the node network. This makes it possible to modify network policy configuration, such as by creating a Linux bridge on all nodes, by applying a single configuration manifest to the cluster.

Node networking is monitored and updated by the following objects:

NodeNetworkState
Reports the state of the network on that node.

NodeNetworkConfigurationPolicy
Describes the requested network configuration on nodes. You update the node network configuration, including adding and removing interfaces, by applying a NodeNetworkConfigurationPolicy manifest to the cluster.

NodeNetworkConfigurationEnactment
Reports the network policies enacted upon each node.

OpenShift Virtualization supports the use of the following nmstate interface types:

- Linux Bridge
- VLAN
- Bond
- Ethernet

NOTE
If your OpenShift Container Platform cluster uses OVN-Kubernetes as the default Container Network Interface (CNI) provider, you cannot attach a Linux bridge or bonding to the default interface of a host because of a change in the host network topology of OVN-Kubernetes. As a workaround, you can use a secondary network interface connected to your host, or switch to the OpenShift SDN default CNI provider.

12.1.2. Viewing the network state of a node

A NodeNetworkState object exists on every node in the cluster. This object is periodically updated and captures the state of the network for that node.

Procedure

1. List all the NodeNetworkState objects in the cluster:

   $ oc get nns
2. Inspect a **NodeNetworkState** object to view the network on that node. The output in this example has been redacted for clarity:

```
$ oc get nns node01 -o yaml
```

**Example output**

```
apiVersion: nmstate.io/v1
kind: NodeNetworkState
metadata:
  name: node01
status:
  currentState:
    dns-resolver:
    ...
  interfaces:
  ...
  route-rules:
  ...
  routes:
  ...
  lastSuccessfulUpdateTime: "2020-01-31T12:14:00Z"
```

1. The name of the **NodeNetworkState** object is taken from the node.
2. The **currentState** contains the complete network configuration for the node, including DNS, interfaces, and routes.
3. Timestamp of the last successful update. This is updated periodically as long as the node is reachable and can be used to evaluate the freshness of the report.

## 12.2. UPDATING NODE NETWORK CONFIGURATION

You can update the node network configuration, such as adding or removing interfaces from nodes, by applying **NodeNetworkConfigurationPolicy** manifests to the cluster.

### 12.2.1. About \texttt{nmstate}

OpenShift Virtualization uses \texttt{nmstate} to report on and configure the state of the node network. This makes it possible to modify network policy configuration, such as by creating a Linux bridge on all nodes, by applying a single configuration manifest to the cluster.

Node networking is monitored and updated by the following objects:

- **NodeNetworkState**
  - Reports the state of the network on that node.

- **NodeNetworkConfigurationPolicy**
  - Describes the requested network configuration on nodes. You update the node network configuration, including adding and removing interfaces, by applying a **NodeNetworkConfigurationPolicy** manifest to the cluster.

- **NodeNetworkConfigurationEnactment**
Reports the network policies enacted upon each node.

OpenShift Virtualization supports the use of the following `nmstate` interface types:

- Linux Bridge
- VLAN
- Bond
- Ethernet

**NOTE**

If your OpenShift Container Platform cluster uses OVN-Kubernetes as the default Container Network Interface (CNI) provider, you cannot attach a Linux bridge or bonding to the default interface of a host because of a change in the host network topology of OVN-Kubernetes. As a workaround, you can use a secondary network interface connected to your host, or switch to the OpenShift SDN default CNI provider.

### 12.2.2. Creating an interface on nodes

Create an interface on nodes in the cluster by applying a `NodeNetworkConfigurationPolicy` manifest to the cluster. The manifest details the requested configuration for the interface.

By default, the manifest applies to all nodes in the cluster. To add the interface to specific nodes, add the `spec: nodeSelector` parameter and the appropriate `<key>:<value>` for your node selector.

You can configure multiple `nmstate`-enabled nodes concurrently. The configuration applies to 50% of the nodes in parallel. This strategy prevents the entire cluster from being unavailable if the network connection fails. To apply the policy configuration in parallel to a specific portion of the cluster, use the `maxUnavailable` field.

**Procedure**

1. Create the `NodeNetworkConfigurationPolicy` manifest. The following example configures a Linux bridge on all worker nodes and configures the DNS resolver:

   ```yaml
   apiVersion: nmstate.io/v1
   kind: NodeNetworkConfigurationPolicy
   metadata:
     name: br1-eth1-policy
   spec:
     nodeSelector:
       - node-role.kubernetes.io/worker: ""
     maxUnavailable: 3
     desiredState:
       interfaces:
         - name: br1
           description: Linux bridge with eth1 as a port
           type: linux-bridge
           state: up
           ipv4: dhcp: true
           enabled: true
   ```
auto-dns: false
bridge:
  options:
  stp:
    enabled: false
port:
  - name: eth1
dns-resolver: 6
config:
space:
  - example.com
  - example.org
server:
  - 8.8.8.8

1 Name of the policy.

2 Optional: If you do not include the nodeSelector parameter, the policy applies to all nodes in the cluster.

3 This example uses the node-role.kubernetes.io/worker: "" node selector to select all worker nodes in the cluster.

4 Optional: Specifies the maximum number of nmstate-enabled nodes that the policy configuration can be applied to concurrently. This parameter can be set to either a percentage value (string), for example, "10%", or an absolute value (number), such as 3.

5 Optional: Human-readable description for the interface.

6 Optional: Specifies the search and server settings for the DNS server.

2. Create the node network policy:

   $ oc apply -f br1-eth1-policy.yaml 1

   1 File name of the node network configuration policy manifest.

Additional resources

- Example policy configurations for different interfaces
- Example for creating multiple interfaces in the same policy
- Examples of different IP management methods in policies

12.2.3. Confirming node network policy updates on nodes

A NodeNetworkConfigurationPolicy manifest describes your requested network configuration for nodes in the cluster. The node network policy includes your requested network configuration and the status of execution of the policy on the cluster as a whole.

When you apply a node network policy, a NodeNetworkConfigurationEnactment object is created for every node in the cluster. The node network configuration enactment is a read-only object that represents the status of execution of the policy on that node. If the policy fails to be applied on the
node, the enactment for that node includes a traceback for troubleshooting.

Procedure

1. To confirm that a policy has been applied to the cluster, list the policies and their status:
   
   $ oc get nncp

2. Optional: If a policy is taking longer than expected to successfully configure, you can inspect the requested state and status conditions of a particular policy:
   
   $ oc get nncp <policy> -o yaml

3. Optional: If a policy is taking longer than expected to successfully configure on all nodes, you can list the status of the enactments on the cluster:
   
   $ oc get nnce

4. Optional: To view the configuration of a particular enactment, including any error reporting for a failed configuration:
   
   $ oc get nnce <node>.<policy> -o yaml

12.2.4. Removing an interface from nodes

You can remove an interface from one or more nodes in the cluster by editing the `NodeNetworkConfigurationPolicy` object and setting the `state` of the interface to `absent`.

Removing an interface from a node does not automatically restore the node network configuration to a previous state. If you want to restore the previous state, you will need to define that node network configuration in the policy.

If you remove a bridge or bonding interface, any node NICs in the cluster that were previously attached or subordinate to that bridge or bonding interface are placed in a `down` state and become unreachable. To avoid losing connectivity, configure the node NIC in the same policy so that it has a status of `up` and either DHCP or a static IP address.

**NOTE**

Deleting the node network policy that added an interface does not change the configuration of the policy on the node. Although a `NodeNetworkConfigurationPolicy` is an object in the cluster, it only represents the requested configuration. Similarly, removing an interface does not delete the policy.

Procedure

1. Update the `NodeNetworkConfigurationPolicy` manifest used to create the interface. The following example removes a Linux bridge and configures the `eth1` NIC with DHCP to avoid losing connectivity:

   ```yaml
   apiVersion: nmstate.io/v1
   kind: NodeNetworkConfigurationPolicy
   metadata:
   ```
Name of the policy.

Optional: If you do not include the `nodeSelector` parameter, the policy applies to all nodes in the cluster.

This example uses the `node-role.kubernetes.io/worker: ""` node selector to select all worker nodes in the cluster.

Changing the state to `absent` removes the interface.

The name of the interface that is to be unattached from the bridge interface.

The type of interface. This example creates an Ethernet networking interface.

The requested state for the interface.

Optional: If you do not use `dhcp`, you can either set a static IP or leave the interface without an IP address.

Enables `ipv4` in this example.

2. Update the policy on the node and remove the interface:

   ```bash
   $ oc apply -f <br1-eth1-policy.yaml>
   ```

   File name of the policy manifest.

### 12.2.5. Example policy configurations for different interfaces

#### 12.2.5.1. Example: Linux bridge interface node network configuration policy

Create a Linux bridge interface on nodes in the cluster by applying a `NodeNetworkConfigurationPolicy` manifest to the cluster.

The following YAML file is an example of a manifest for a Linux bridge interface. It includes samples values that you must replace with your own information.
Name of the policy.  
Optional: If you do not include the nodeSelector parameter, the policy applies to all nodes in the cluster.  
This example uses a hostname node selector.  
Name of the interface.  
Optional: Human-readable description of the interface.  
The type of interface. This example creates a bridge.  
The requested state for the interface after creation.  
Optional: If you do not use dhcp, you can either set a static IP or leave the interface without an IP address.  
Enables ipv4 in this example.  
Disables stp in this example.  
The node NIC to which the bridge attaches.  

12.2.5.2. Example: VLAN interface node network configuration policy

Create a VLAN interface on nodes in the cluster by applying a NodeNetworkConfigurationPolicy manifest to the cluster.

The following YAML file is an example of a manifest for a VLAN interface. It includes samples values that you must replace with your own information.
apiVersion: nmstate.io/v1
kind: NodeNetworkConfigurationPolicy
metadata:
  name: vlan-eth1-policy
spec:
  nodeSelector:
    kubernetes.io/hostname: <node01>
desiredState:
  interfaces:
  - name: eth1
    description: VLAN using eth1
    type: vlan
    state: up
    vlan:
      base-iface: eth1
      id: 102

Name of the policy.

Optional: If you do not include the nodeSelector parameter, the policy applies to all nodes in the cluster.

This example uses a hostname node selector.

Name of the interface.

Optional: Human-readable description of the interface.

The type of interface. This example creates a VLAN.

The requested state for the interface after creation.

The node NIC to which the VLAN is attached.

The VLAN tag.

12.2.5.3. Example: Bond interface node network configuration policy

Create a bond interface on nodes in the cluster by applying a NodeNetworkConfigurationPolicy manifest to the cluster.

NOTE

OpenShift Virtualization only supports the following bond modes:

- mode=1 active-backup
- mode=2 balance-xor
- mode=4 802.3ad
- mode=5 balance-trlb
- mode=6 balance-alb
The following YAML file is an example of a manifest for a bond interface. It includes samples values that you must replace with your own information.

```yaml
apiVersion: nmstate.io/v1
kind: NodeNetworkConfigurationPolicy
metadata:
  name: bond0-eth1-eth2-policy
spec:
  nodeSelector:
    kubernetes.io/hostname: <node01>
  desiredState:
    interfaces:
      - name: bond0
        description: Bond with ports eth1 and eth2
        type: bond
        state: up
        ipv4:
          dhcp: true
          enabled: true
        link-aggregation:
          mode: active-backup
          options:
            miimon: '140'
          port:
            - eth1
            - eth2
        mtu: 1450
```

1. Name of the policy.
2. Optional: If you do not include the `nodeSelector` parameter, the policy applies to all nodes in the cluster.
3. This example uses a `hostname` node selector.
4. Name of the interface.
5. Optional: Human-readable description of the interface.
6. The type of interface. This example creates a bond.
7. The requested state for the interface after creation.
8. Optional: If you do not use `dhcp`, you can either set a static IP or leave the interface without an IP address.
9. Enables `ipv4` in this example.
10. The driver mode for the bond. This example uses an active backup mode.
11. Optional: This example uses miimon to inspect the bond link every 140ms.
12. The subordinate node NICs in the bond.
13. Optional: The maximum transmission unit (MTU) for the bond. If not specified, this value is set to 1500 by default.
1500 by default.

12.2.5.4. Example: Ethernet interface node network configuration policy

Configure an Ethernet interface on nodes in the cluster by applying a `NodeNetworkConfigurationPolicy` manifest to the cluster.

The following YAML file is an example of a manifest for an Ethernet interface. It includes sample values that you must replace with your own information.

```yaml
apiVersion: nmstate.io/v1
kind: NodeNetworkConfigurationPolicy
metadata:
  name: eth1-policy
spec:
  nodeSelector:
    kubernetes.io/hostname: <node01>
  desiredState:
    interfaces:
      - name: eth1
        description: Configuring eth1 on node01
        type: ethernet
        state: up
        ipv4:
          dhcp: true
          enabled: true
```

1. Name of the policy.
2. Optional: If you do not include the `nodeSelector` parameter, the policy applies to all nodes in the cluster.
3. This example uses a `hostname` node selector.
4. Name of the interface.
5. Optional: Human-readable description of the interface.
6. The type of interface. This example creates an Ethernet networking interface.
7. The requested state for the interface after creation.
8. Optional: If you do not use `dhcp`, you can either set a static IP or leave the interface without an IP address.
9. Enables `ipv4` in this example.

12.2.5.5. Example: Multiple interfaces in the same node network configuration policy

You can create multiple interfaces in the same node network configuration policy. These interfaces can reference each other, allowing you to build and deploy a network configuration by using a single policy manifest.
The following example snippet creates a bond that is named `bond10` across two NICs and a Linux bridge that is named `br1` that connects to the bond.

```
#...
interfaces:
- name: bond10
  description: Bonding eth2 and eth3 for Linux bridge
  type: bond
  state: up
  link-aggregation:
    port:
    - eth2
    - eth3
- name: br1
  description: Linux bridge on bond
  type: linux-bridge
  state: up
  bridge:
    port:
      - name: bond10
#...
```

12.2.6. Capturing the static IP of a NIC attached to a bridge

**IMPORTANT**

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

For more information about the support scope of Red Hat Technology Preview features, see [https://access.redhat.com/support/offerings/techpreview/](https://access.redhat.com/support/offerings/techpreview/).

12.2.6.1. Example: Linux bridge interface node network configuration policy to inherit static IP address from the NIC attached to the bridge

Create a Linux bridge interface on nodes in the cluster and transfer the static IP configuration of the NIC to the bridge by applying a single `NodeNetworkConfigurationPolicy` manifest to the cluster.

The following YAML file is an example of a manifest for a Linux bridge interface. It includes sample values that you must replace with your own information.

```
apiVersion: nmstate.io/v1
kind: NodeNetworkConfigurationPolicy
metadata:
  name: br1-eth1-copy-ipv4-policy
spec:
  nodeSelector:
    node-role.kubernetes.io/worker: ""
  capture:
    eth1-nic: interfaces.name=="eth1"
    eth1-routes: routes.running.next-hop-interface=="eth1"
```
br1-routes: capture.eth1-routes | routes.running.next-hop-interface := "br1"

desiredState:
interfaces:
- name: br1
  description: Linux bridge with eth1 as a port
  type: linux-bridge
  state: up
  ipv4: "{{ capture.eth1-nic.interfaces.0.ipv4 }}"

bridge:
  options:
    stp:
      enabled: false
    port:
      - name: eth1

routes:
  config: "{{ capture.br1-routes.routes.running }}"

---

1. The name of the policy.
2. Optional: If you do not include the `nodeSelector` parameter, the policy applies to all nodes in the cluster. This example uses the `node-role.kubernetes.io/worker: ""` node selector to select all worker nodes in the cluster.
3. The reference to the node NIC to which the bridge attaches.
4. The type of interface. This example creates a bridge.
5. The IP address of the bridge interface. This value matches the IP address of the NIC which is referenced by the `spec.capture.eth1-nic` entry.
6. The node NIC to which the bridge attaches.

Additional resources
- The NMPolicy project - Policy syntax

### 12.2.7. Examples: IP management

The following example configuration snippets demonstrate different methods of IP management.

These examples use the `ethernet` interface type to simplify the example while showing the related context in the policy configuration. These IP management examples can be used with the other interface types.

#### 12.2.7.1. Static

The following snippet statically configures an IP address on the Ethernet interface:
Replace this value with the static IP address for the interface.

12.2.7.2. No IP address

The following snippet ensures that the interface has no IP address:

```yaml
... interfaces: - name: eth1   description: No IP on eth1   type: ethernet   state: up   ipv4:     enabled: false
...```

12.2.7.3. Dynamic host configuration

The following snippet configures an Ethernet interface that uses a dynamic IP address, gateway address, and DNS:

```yaml
... interfaces: - name: eth1   description: DHCP on eth1   type: ethernet   state: up   ipv4:      dhcp: true      enabled: true
...```

The following snippet configures an Ethernet interface that uses a dynamic IP address but does not use a dynamic gateway address or DNS:

```yaml
... interfaces: - name: eth1   description: DHCP without gateway or DNS on eth1   type: ethernet   state: up   ipv4:      dhcp: true      auto-gateway: false
...```
12.2.7.4. DNS

Setting the DNS configuration is analogous to modifying the `/etc/resolv.conf` file. The following snippet sets the DNS configuration on the host.

```
auto-dns: false
enabled: true
```

**IMPORTANT**

You must configure an interface with `auto-dns: false` or you must use static IP configuration on an interface in order for Kubernetes NMState to store custom DNS settings.

You cannot use `br-ex`, an OVN Kubernetes-managed Open vSwitch bridge, as the interface when configuring DNS resolvers.

12.2.7.5. Static routing

The following snippet configures a static route and a static IP on interface `eth1`.

```
interfaces:
  - name: eth1
description: Static routing on eth1
type: ethernet
state: up
ipv4:
  address:
    - ip: 192.0.2.251
description: Static routing on eth1
prefix-length: 24
enabled: true
routes:
  config:
    - destination: 198.51.100.0/24
metric: 150
next-hop-address: 192.0.2.1
```
next-hop-interface: eth1
table-id: 254
...

1. The static IP address for the Ethernet interface.
2. Next hop address for the node traffic. This must be in the same subnet as the IP address set for the Ethernet interface.

12.3. TROUBLESHOOTING NODE NETWORK CONFIGURATION

If the node network configuration encounters an issue, the policy is automatically rolled back and the enactments report failure. This includes issues such as:

- The configuration fails to be applied on the host.
- The host loses connection to the default gateway.
- The host loses connection to the API server.

12.3.1. Troubleshooting an incorrect node network configuration policy configuration

You can apply changes to the node network configuration across your entire cluster by applying a node network configuration policy. If you apply an incorrect configuration, you can use the following example to troubleshoot and correct the failed node network policy.

In this example, a Linux bridge policy is applied to an example cluster that has three control plane nodes (master) and three compute (worker) nodes. The policy fails to be applied because it references an incorrect interface. To find the error, investigate the available NMState resources. You can then update the policy with the correct configuration.

Procedure

1. Create a policy and apply it to your cluster. The following example creates a simple bridge on the ens01 interface:

```yaml
apiVersion: nmstate.io/v1
kind: NodeNetworkConfigurationPolicy
metadata:
  name: ens01-bridge-testfail
spec:
desiredState:
  interfaces:
    - name: br1
description: Linux bridge with the wrong port
type: linux-bridge
state: up
ipv4:
dhcp: true
enabled: true
bridge:
  options:
stp:
```
2. Verify the status of the policy by running the following command:

```sh
$ oc get nncp
```

The output shows that the policy failed:

**Example output**

```
NAME                    STATUS
ens01-bridge-testfail   FailedToConfigure
```

However, the policy status alone does not indicate if it failed on all nodes or a subset of nodes.

3. List the node network configuration enactments to see if the policy was successful on any of the nodes. If the policy failed for only a subset of nodes, it suggests that the problem is with a specific node configuration. If the policy failed on all nodes, it suggests that the problem is with the policy.

```sh
$ oc get nnce
```

The output shows that the policy failed on all nodes:

**Example output**

```
NAME                                   STATUS
control-plane-1.ens01-bridge-testfail   FailedToConfigure
control-plane-2.ens01-bridge-testfail   FailedToConfigure
control-plane-3.ens01-bridge-testfail   FailedToConfigure
compute-1.ens01-bridge-testfail         FailedToConfigure
compute-2.ens01-bridge-testfail         FailedToConfigure
compute-3.ens01-bridge-testfail         FailedToConfigure
```

4. View one of the failed enactments and look at the traceback. The following command uses the output tool `jsonpath` to filter the output:

```sh
$ oc get nnce compute-1.ens01-bridge-testfail -o jsonpath='{.status.conditions[?(@.type=="Failing")].message}'
```

This command returns a large traceback that has been edited for brevity:

**Example output**

```
error reconciling NodeNetworkConfigurationPolicy at desired state apply: , failed to execute
```
nmstatectl set --no-commit --timeout 480: 'exit status 1' "
...
libnmstate.error.NmstateVerificationError:
desired
========
---
name: br1
type: linux-bridge
state: up
bridge:
  options:
    group-forward-mask: 0
    mac-ageing-time: 300
    multicast-snooping: true
    stp:
      enabled: false
      forward-delay: 15
      hello-time: 2
      max-age: 20
      priority: 32768
  port:
    - name: ens01
description: Linux bridge with the wrong port
ipv4:
  address: []
  auto-dns: true
  auto-gateway: true
  auto-routes: true
dhcp: true
  enabled: true
ipv6:
  enabled: false
mac-address: 01-23-45-67-89-AB
mtu: 1500
---

current
========
---
name: br1
type: linux-bridge
state: up
bridge:
  options:
    group-forward-mask: 0
    mac-ageing-time: 300
    multicast-snooping: true
    stp:
      enabled: false
      forward-delay: 15
      hello-time: 2
      max-age: 20
      priority: 32768
  port: []
description: Linux bridge with the wrong port
ipv4:
  address: []
The `NmstateVerificationError` lists the desired policy configuration, the current configuration of the policy on the node, and the difference highlighting the parameters that do not match. In this example, the port is included in the difference, which suggests that the problem is the port configuration in the policy.

5. To ensure that the policy is configured properly, view the network configuration for one or all of the nodes by requesting the `NodeNetworkState` object. The following command returns the network configuration for the `control-plane-1` node:

```bash
$ oc get nns control-plane-1 -o yaml
```

The output shows that the interface name on the nodes is `ens1` but the failed policy incorrectly uses `ens01`:

**Example output**

```yaml
- ipv4:
  ...  
  name: ens1  
  state: up  
  type: ethernet
```

6. Correct the error by editing the existing policy:

```bash
$ oc edit nncp ens01-bridge-testfail
```
... port:
    - name: ens1

Save the policy to apply the correction.

7. Check the status of the policy to ensure it updated successfully:

```bash
$ oc get nncp
```

**Example output**

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ens01-bridge-testfail</td>
<td>SuccessfullyConfigured</td>
</tr>
<tr>
<td>ens01-bridge-testfail</td>
<td>SuccessfullyConfigured</td>
</tr>
</tbody>
</table>

The updated policy is successfully configured on all nodes in the cluster.
CHAPTER 13. LOGGING, EVENTS, AND MONITORING

13.1. REVIEWING VIRTUALIZATION OVERVIEW

The Virtualization Overview page provides a comprehensive view of virtualization resources, details, status, and top consumers. By gaining an insight into the overall health of OpenShift Virtualization, you can determine if intervention is required to resolve specific issues identified by examining the data.

Use the Getting Started resources to access quick starts, read the latest blogs on virtualization, and learn how to use operators. Obtain complete information about alerts, events, inventory, and status of virtual machines. Customize the Top Consumer cards to obtain data on high utilization of a specific resource by projects, virtual machines, or nodes. Click View virtualization dashboard for quick access to the Dashboards page.

13.1.1. Prerequisites

To use the vCPU wait metric in the Top Consumers card, the schedstats-enable kernel argument must be applied to the MachineConfig object. This kernel argument enables scheduler statistics used for debugging and performance tuning and adds a minor additional load to the scheduler. See the OpenShift Container Platform machine configuration tasks documentation for more information on applying a kernel argument.

13.1.2. Resources monitored actively in the Virtualization Overview page

The following table shows actively monitored resources, metrics, and fields in the Virtualization Overview page. This information is useful when you need to obtain relevant data and intervene to resolve a problem.

<table>
<thead>
<tr>
<th>Monitored resources, fields, and metrics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Details</td>
<td>A brief overview of service and version information for OpenShift Virtualization.</td>
</tr>
<tr>
<td>Status</td>
<td>Alerts for virtualization and networking.</td>
</tr>
<tr>
<td>Activity</td>
<td>Ongoing events for virtual machines. Messages are related to recent activity in the cluster, such as pod creation or virtual machine migration to another host.</td>
</tr>
<tr>
<td>Running VMs by Template</td>
<td>The donut chart displays a unique color for each virtual machine template and shows the number of running virtual machines that use each template.</td>
</tr>
<tr>
<td>Inventory</td>
<td>Total number of active virtual machines, templates, nodes, and networks.</td>
</tr>
<tr>
<td>Status of VMs</td>
<td>Current status of virtual machines: running, provisioning, starting, migrating, paused, stopping, terminating, and unknown.</td>
</tr>
</tbody>
</table>
Permissions

| Permissions | Tasks for which capabilities are enabled through permissions: Access to public templates, Access to public boot sources, Clone a VM, Attach VM to multiple networks, Upload a base image from local disk, and Share templates. |

13.1.3. Resources monitored for top consumption

The Top Consumers cards in Virtualization Overview page display projects, virtual machines or nodes with maximum consumption of a resource. You can select a project, a virtual machine, or a node and view the top five or top ten consumers of a specific resource.

**NOTE**

Viewing the maximum resource consumption is limited to the top five or top ten consumers within each Top Consumers card.

The following table shows resources monitored for top consumers.

<table>
<thead>
<tr>
<th>Resources monitored for top consumption</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Projects, virtual machines, or nodes consuming the most CPU.</td>
</tr>
<tr>
<td>Memory</td>
<td>Projects, virtual machines, or nodes consuming the most memory (in bytes). The unit of display (for example, MiB or GiB) is determined by the size of the resource consumption.</td>
</tr>
<tr>
<td>Used filesystem</td>
<td>Projects, virtual machines, or nodes with the highest consumption of filesystems (in bytes). The unit of display (for example, MiB or GiB) is determined by the size of the resource consumption.</td>
</tr>
<tr>
<td>Memory swap</td>
<td>Projects, virtual machines, or nodes consuming the most memory pressure when memory is swapped.</td>
</tr>
<tr>
<td>vCPU wait</td>
<td>Projects, virtual machines, or nodes experiencing the maximum wait time (in seconds) for the vCPUs.</td>
</tr>
<tr>
<td>Storage throughput</td>
<td>Projects, virtual machines, or nodes with the highest data transfer rate to and from the storage media (in mbps).</td>
</tr>
<tr>
<td>Storage IOPS</td>
<td>Projects, virtual machines, or nodes with the highest amount of storage IOPS (input/output operations per second) over a time period.</td>
</tr>
</tbody>
</table>
13.1.4. Reviewing top consumers for projects, virtual machines, and nodes

You can view the top consumers of resources for a selected project, virtual machine, or node in the Virtualization Overview page.

Prerequisites

- You have access to the cluster as a user with the cluster-admin role.

Procedure

1. In the Administrator perspective in the OpenShift Virtualization web console, navigate to Virtualization → Overview.

2. Navigate to the Top Consumers cards.

3. From the drop-down menu, select Show top 5 or Show top 10.

4. For a Top Consumer card, select the type of resource from the drop-down menu: CPU, Memory, Used Filesystem, Memory Swap, vCPU Wait, or Storage Throughput.

5. Select By Project, By VM, or By Node. A list of the top five or top ten consumers of the selected resource is displayed.

13.1.5. Additional resources

- Monitoring overview
- Reviewing monitoring dashboards
- Dashboards

13.2. VIEWING VIRTUAL MACHINE LOGS

13.2.1. About virtual machine logs

Logs are collected for OpenShift Container Platform builds, deployments, and pods. In OpenShift Virtualization, virtual machine logs can be retrieved from the virtual machine launcher pod in either the web console or the CLI.

The -f option follows the log output in real time, which is useful for monitoring progress and error checking.

If the launcher pod is failing to start, use the --previous option to see the logs of the last attempt.

WARNING

ErrImagePull and ImagePullBackOff errors can be caused by an incorrect deployment configuration or problems with the images that are referenced.
13.2.2. Viewing virtual machine logs in the CLI

Get virtual machine logs from the virtual machine launcher pod.

**Procedure**

- Use the following command:
  
  `$ oc logs <virt-launcher-name>`

13.2.3. Viewing virtual machine logs in the web console

Get virtual machine logs from the associated virtual machine launcher pod.

**Procedure**

1. In the OpenShift Virtualization console, click **Workloads → Virtualization** from the side menu.
2. Click the **Virtual Machines** tab.
3. Select a virtual machine to open the **Virtual Machine Overview** screen.
4. In the **Details** tab, click the **virt-launcher-<name>** pod in the **Pod** section.
5. Click **Logs**.

13.3. VIEWING EVENTS

13.3.1. About virtual machine events

OpenShift Container Platform events are records of important life-cycle information in a namespace and are useful for monitoring and troubleshooting resource scheduling, creation, and deletion issues.

OpenShift Virtualization adds events for virtual machines and virtual machine instances. These can be viewed from either the web console or the CLI.

See also: [Viewing system event information in an OpenShift Container Platform cluster](#).

13.3.2. Viewing the events for a virtual machine in the web console

You can view the stream events for a running a virtual machine from the **Virtual Machine Overview** panel of the web console.

The ■ button pauses the events stream.

The ▶ button continues a paused events stream.

**Procedure**

1. Click **Workloads → Virtualization** from the side menu.
2. Click the **Virtual Machines** tab.
3. Select a virtual machine to open the **Virtual Machine Overview** screen.
4. Click **Events** to view all events for the virtual machine.

### 13.3.3. Viewing namespace events in the CLI

Use the OpenShift Container Platform client to get the events for a namespace.

**Procedure**

- In the namespace, use the `oc get` command:

  ```
  $ oc get events
  ```

### 13.3.4. Viewing resource events in the CLI

Events are included in the resource description, which you can get using the OpenShift Container Platform client.

**Procedure**

- In the namespace, use the `oc describe` command. The following example shows how to get the events for a virtual machine, a virtual machine instance, and the virt-launcher pod for a virtual machine:

  ```
  $ oc describe vm <vm>
  $ oc describe vmi <vmi>
  $ oc describe pod virt-launcher-<name>
  ```

### 13.4. DIAGONOSING DATA VOLUMES USING EVENTS AND CONDITIONS

Use the `oc describe` command to analyze and help resolve issues with data volumes.

#### 13.4.1. About conditions and events

Diagnose data volume issues by examining the output of the **Conditions** and **Events** sections generated by the command:

```
$ oc describe dv <DataVolume>
```

There are three **Types** in the **Conditions** section that display:

- **Bound**
- **Running**
- **Ready**

The **Events** section provides the following additional information:

- **Type** of event
Reason for logging

Source of the event

Message containing additional diagnostic information.

The output from `oc describe` does not always contain Events.

An event is generated when either Status, Reason, or Message changes. Both conditions and events react to changes in the state of the data volume.

For example, if you misspell the URL during an import operation, the import generates a 404 message. That message change generates an event with a reason. The output in the Conditions section is updated as well.

13.4.2. Analyzing data volumes using conditions and events

By inspecting the Conditions and Events sections generated by the describe command, you determine the state of the data volume in relation to persistent volume claims (PVCs), and whether or not an operation is actively running or completed. You might also receive messages that offer specific details about the status of the data volume, and how it came to be in its current state.

There are many different combinations of conditions. Each must be evaluated in its unique context.

Examples of various combinations follow.

- **Bound** – A successfully bound PVC displays in this example.
  
  Note that the Type is Bound, so the Status is True. If the PVC is not bound, the Status is False.

  When the PVC is bound, an event is generated stating that the PVC is bound. In this case, the Reason is Bound and Status is True. The Message indicates which PVC owns the data volume.

  Message, in the Events section, provides further details including how long the PVC has been bound (Age) and by what resource (From), in this case datavolume-controller.

Example output

<table>
<thead>
<tr>
<th>Status:</th>
<th>Conditions:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Last Heart Beat Time: 2020-07-15T03:58:24Z</td>
</tr>
<tr>
<td></td>
<td>Last Transition Time: 2020-07-15T03:58:24Z</td>
</tr>
<tr>
<td></td>
<td>Message: PVC win10-rootdisk Bound</td>
</tr>
<tr>
<td></td>
<td>Reason: Bound</td>
</tr>
<tr>
<td></td>
<td>Status: True</td>
</tr>
<tr>
<td></td>
<td>Type: Bound</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Events: Type</th>
<th>Reason</th>
<th>Age</th>
<th>From</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Bound</td>
<td>24s</td>
<td>datavolume-controller</td>
<td>PVC example-dv Bound</td>
</tr>
</tbody>
</table>

- **Running** – In this case, note that Type is Running and Status is False, indicating that an event has occurred that caused an attempted operation to fail, changing the Status from True to False.
However, note that **Reason** is **Completed** and the **Message** field indicates **Import Complete**.

In the **Events** section, the **Reason** and **Message** contain additional troubleshooting information about the failed operation. In this example, the **Message** displays an inability to connect due to a **404**, listed in the **Events** section’s first **Warning**.

From this information, you conclude that an import operation was running, creating contention for other operations that are attempting to access the data volume:

**Example output**

```
Status:
Conditions:
Message: Import Complete
Reason: Completed
Status: False
Type: Running

Events:
  Type     Reason           Age                From                   Message
  ------     ------           ----               ----                   -------
  Warning   Error            12s (x2 over 14s)  datavolume-controller  Unable to connect
to http data source: expected status code 200, got 404. Status: 404 Not Found
```

- **Ready** – If **Type** is **Ready** and **Status** is **True**, then the data volume is ready to be used, as in the following example. If the data volume is not ready to be used, the **Status** is **False**:

**Example output**

```
Status:
Conditions:
Status: True
Type: Ready
```

### 13.5. VIEWING INFORMATION ABOUT VIRTUAL MACHINE WORKLOADS

You can view high-level information about your virtual machines by using the **Virtual Machines** dashboard in the OpenShift Container Platform web console.

#### 13.5.1. About the Virtual Machines dashboard

Access virtual machines from the OpenShift Container Platform web console by navigating to the **Workloads → Virtualization** page. The **Workloads → Virtualization** page contains two tabs: **Virtual Machines** * Virtual Machine Templates

The following cards describe each virtual machine:

- **Details** provides identifying information about the virtual machine, including:
Inventory lists the virtual machine’s resources, including:
- Network interface controllers (NICs)
- Disks

Status includes:
- The current status of the virtual machine
- A note indicating whether or not the QEMU guest agent is installed on the virtual machine

Utilization includes charts that display usage data for:
- CPU
- Memory
- Filesystem
- Network transfer

NOTE
Use the drop-down list to choose a duration for the utilization data. The available options are 1 Hour, 6 Hours, and 24 Hours.

Events lists messages about virtual machine activity over the past hour. To view additional events, click View all.

13.6. MONITORING VIRTUAL MACHINE HEALTH

A virtual machine instance (VMI) can become unhealthy due to transient issues such as connectivity loss, deadlocks, or problems with external dependencies. A health check periodically performs diagnostics on a VMI by using any combination of the readiness and liveness probes.

13.6.1. About readiness and liveness probes

Use readiness and liveness probes to detect and handle unhealthy virtual machine instances (VMIs). You can include one or more probes in the specification of the VMI to ensure that traffic does not reach a VMI that is not ready for it and that a new instance is created when a VMI becomes unresponsive.

A readiness probe determines whether a VMI is ready to accept service requests. If the probe fails, the VMI is removed from the list of available endpoints until the VMI is ready.
A *liveness probe* determines whether a VMI is responsive. If the probe fails, the VMI is deleted and a new instance is created to restore responsiveness.

You can configure readiness and liveness probes by setting the `spec.readinessProbe` and the `spec.livenessProbe` fields of the `VirtualMachineInstance` object. These fields support the following tests:

**HTTP GET**

The probe determines the health of the VMI by using a web hook. The test is successful if the HTTP response code is between 200 and 399. You can use an HTTP GET test with applications that return HTTP status codes when they are completely initialized.

**TCP socket**

The probe attempts to open a socket to the VMI. The VMI is only considered healthy if the probe can establish a connection. You can use a TCP socket test with applications that do not start listening until initialization is complete.

### 13.6.2. Defining an HTTP readiness probe

Define an HTTP readiness probe by setting the `spec.readinessProbe.httpGet` field of the virtual machine instance (VMI) configuration.

**Procedure**

1. Include details of the readiness probe in the VMI configuration file.

**Sample readiness probe with an HTTP GET test**

```yaml
# ...
spec:
  readinessProbe:
    httpGet: 1
      port: 1500 2
      path: /healthz 3
      httpHeaders:
        - name: Custom-Header
          value: Awesome
      initialDelaySeconds: 120 4
      periodSeconds: 20 5
      timeoutSeconds: 10 6
      failureThreshold: 3 7
      successThreshold: 3 8
# ...
```

1. The HTTP GET request to perform to connect to the VMI.
2. The port of the VMI that the probe queries. In the above example, the probe queries port 1500.
3. The path to access on the HTTP server. In the above example, if the handler for the server’s `/healthz` path returns a success code, the VMI is considered to be healthy. If the handler returns a failure code, the VMI is removed from the list of available endpoints.
4. The time, in seconds, after the VMI starts before the readiness probe is initiated.
5. The delay, in seconds, between performing probes. The default delay is 10 seconds. This value must be greater than `timeoutSeconds`.

6. The number of seconds of inactivity after which the probe times out and the VMI is assumed to have failed. The default value is 1. This value must be lower than `periodSeconds`.

7. The number of times that the probe is allowed to fail. The default is 3. After the specified number of attempts, the pod is marked **unready**.

8. The number of times that the probe must report success, after a failure, to be considered successful. The default is 1.

2. Create the VMI by running the following command:

```
$ oc create -f <file_name>.yaml
```

### 13.6.3. Defining a TCP readiness probe

Define a TCP readiness probe by setting the `spec.readinessProbe.tcpSocket` field of the virtual machine instance (VMI) configuration.

**Procedure**

1. Include details of the TCP readiness probe in the VMI configuration file.

   **Sample readiness probe with a TCP socket test**

   ```yaml
   ...
   spec:
     readinessProbe:
       initialDelaySeconds: 120
       periodSeconds: 20
       tcpSocket:
         port: 1500
         timeoutSeconds: 10
   ...
   ```

   1. The time, in seconds, after the VMI starts before the readiness probe is initiated.

   2. The delay, in seconds, between performing probes. The default delay is 10 seconds. This value must be greater than `timeoutSeconds`.

   3. The TCP action to perform.

   4. The port of the VMI that the probe queries.

   5. The number of seconds of inactivity after which the probe times out and the VMI is assumed to have failed. The default value is 1. This value must be lower than `periodSeconds`.

2. Create the VMI by running the following command:

```
$ oc create -f <file_name>.yaml
```
13.6.4. Defining an HTTP liveness probe

Define an HTTP liveness probe by setting the `spec.livenessProbe.httpGet` field of the virtual machine instance (VMI) configuration. You can define both HTTP and TCP tests for liveness probes in the same way as readiness probes. This procedure configures a sample liveness probe with an HTTP GET test.

Procedure

1. Include details of the HTTP liveness probe in the VMI configuration file.

Sample liveness probe with an HTTP GET test

```yaml
# ...
spec:
  livenessProbe:
    initialDelaySeconds: 120
    periodSeconds: 20
    httpGet:
      port: 1500
      path: /healthz
      httpHeaders:
        - name: Custom-Header
          value: Awesome
      timeoutSeconds: 10
# ...
```

1. The time, in seconds, after the VMI starts before the liveness probe is initiated.
2. The delay, in seconds, between performing probes. The default delay is 10 seconds. This value must be greater than `timeoutSeconds`.
3. The HTTP GET request to perform to connect to the VMI.
4. The port of the VMI that the probe queries. In the above example, the probe queries port 1500. The VMI installs and runs a minimal HTTP server on port 1500 via cloud-init.
5. The path to access on the HTTP server. In the above example, if the handler for the server’s `/healthz` path returns a success code, the VMI is considered to be healthy. If the handler returns a failure code, the VMI is deleted and a new instance is created.
6. The number of seconds of inactivity after which the probe times out and the VMI is assumed to have failed. The default value is 1. This value must be lower than `periodSeconds`.

2. Create the VMI by running the following command:

```
$ oc create -f <file_name>.yaml
```

13.6.5. Template: Virtual machine configuration file for defining health checks
Monitoring application health by using health checks

13.6.6. Additional resources

- Monitoring application health by using health checks
13.7. USING THE OPENSHIFT CONTAINER PLATFORM DASHBOARD TO GET CLUSTER INFORMATION

Access the OpenShift Container Platform dashboard, which captures high-level information about the cluster, by clicking **Home > Dashboards > Overview** from the OpenShift Container Platform web console.

The OpenShift Container Platform dashboard provides various cluster information, captured in individual dashboard cards.

13.7.1. About the OpenShift Container Platform dashboards page

The OpenShift Container Platform dashboard consists of the following cards:

- **Details** provides a brief overview of informational cluster details. Status include **ok**, **error**, **warning**, **in progress**, and **unknown**. Resources can add custom status names.
  - Cluster ID
  - Provider
  - Version

- **Cluster Inventory** details number of resources and associated statuses. It is helpful when intervention is required to resolve problems, including information about:
  - Number of nodes
  - Number of pods
  - Persistent storage volume claims
  - Virtual machines (available if OpenShift Virtualization is installed)
  - Bare metal hosts in the cluster, listed according to their state (only available in **metal3** environment)

- **Cluster Health** summarizes the current health of the cluster as a whole, including relevant alerts and descriptions. If OpenShift Virtualization is installed, the overall health of OpenShift Virtualization is diagnosed as well. If more than one subsystem is present, click **See All** to view the status of each subsystem.

- **Cluster Capacity** charts help administrators understand when additional resources are required in the cluster. The charts contain an inner ring that displays current consumption, while an outer ring displays thresholds configured for the resource, including information about:
  - CPU time
  - Memory allocation
  - Storage consumed
  - Network resources consumed

- **Cluster Utilization** shows the capacity of various resources over a specified period of time, to help administrators understand the scale and frequency of high resource consumption.
• **Events** lists messages related to recent activity in the cluster, such as pod creation or virtual machine migration to another host.

• **Top Consumers** helps administrators understand how cluster resources are consumed. Click on a resource to jump to a detailed page listing pods and nodes that consume the largest amount of the specified cluster resource (CPU, memory, or storage).

### 13.8. REVIEWING RESOURCE USAGE BY VIRTUAL MACHINES

Dashboards in the OpenShift Container Platform web console provide visual representations of cluster metrics to help you to quickly understand the state of your cluster. Dashboards belong to the Monitoring overview that provides monitoring for core platform components.

The OpenShift Virtualization dashboard provides data on resource consumption for virtual machines and associated pods. The visualization metrics displayed in the OpenShift Virtualization dashboard are based on Prometheus Query Language (PromQL) queries.

A monitoring role is required to monitor user-defined namespaces in the OpenShift Virtualization dashboard.

#### 13.8.1. About reviewing top consumers

In the OpenShift Virtualization dashboard, you can select a specific time period and view the top consumers of resources within that time period. Top consumers are virtual machines or virt-launcher pods that are consuming the highest amount of resources.

The following table shows resources monitored in the dashboard and describes the metrics associated with each resource for top consumers.

<table>
<thead>
<tr>
<th>Monitored resources</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory swap traffic</td>
<td>Virtual machines consuming the most memory pressure when swapping memory.</td>
</tr>
<tr>
<td>vCPU wait</td>
<td>Virtual machines experiencing the maximum wait time (in seconds) for their vCPUs.</td>
</tr>
<tr>
<td>CPU usage by pod</td>
<td>The <strong>virt-launcher</strong> pods that are using the most CPU.</td>
</tr>
<tr>
<td>Network traffic</td>
<td>Virtual machines that are saturating the network by receiving the most amount of network traffic (in bytes).</td>
</tr>
<tr>
<td>Storage traffic</td>
<td>Virtual machines with the highest amount (in bytes) of storage-related traffic.</td>
</tr>
<tr>
<td>Storage IOPS</td>
<td>Virtual machines with the highest amount of I/O operations per second over a time period.</td>
</tr>
<tr>
<td>Memory usage</td>
<td>The <strong>virt-launcher</strong> pods that are using the most memory (in bytes).</td>
</tr>
</tbody>
</table>
13.8.2. Reviewing top consumers

In the Administrator perspective, you can view the OpenShift Virtualization dashboard where top consumers of resources are displayed.

Prerequisites

- You have access to the cluster as a user with the `cluster-admin` role.

Procedure

1. In the Administrator perspective in the OpenShift Virtualization web console, navigate to Observe → Dashboards.
2. Select the KubeVirt/Infrastructure Resources/Top Consumers dashboard from the Dashboard list.
3. Select a predefined time period from the drop-down menu for Period. You can review the data for top consumers in the tables.
4. Optional: Click Inspect to view or edit the Prometheus Query Language (PromQL) query associated with the top consumers for a table.

13.8.3. Additional resources

- Monitoring overview
- Reviewing monitoring dashboards

13.9. OPENSHIFT CONTAINER PLATFORM CLUSTER MONITORING, LOGGING, AND TELEMETRY

OpenShift Container Platform provides various resources for monitoring at the cluster level.

13.9.1. About OpenShift Container Platform monitoring

OpenShift Container Platform includes a pre-configured, pre-installed, and self-updating monitoring stack that provides monitoring for core platform components. OpenShift Container Platform delivers monitoring best practices out of the box. A set of alerts are included by default that immediately notify cluster administrators about issues with a cluster. Default dashboards in the OpenShift Container Platform web console include visual representations of cluster metrics to help you to quickly understand the state of your cluster.

After installing OpenShift Container Platform 4.10, cluster administrators can optionally enable monitoring for user-defined projects. By using this feature, cluster administrators, developers, and other users can specify how services and pods are monitored in their own projects. You can then query metrics, review dashboards, and manage alerting rules and silences for your own projects in the OpenShift Container Platform web console.
Cluster administrators can grant developers and other users permission to monitor their own projects. Privileges are granted by assigning one of the predefined monitoring roles.

### 13.9.2. About logging subsystem components

The logging subsystem components include a collector deployed to each node in the OpenShift Container Platform cluster that collects all node and container logs and writes them to a log store. You can use a centralized web UI to create rich visualizations and dashboards with the aggregated data.

The major components of the logging subsystem are:

- **collection** - This is the component that collects logs from the cluster, formats them, and forwards them to the log store. The current implementation is Fluentd.

- **log store** - This is where the logs are stored. The default implementation is Elasticsearch. You can use the default Elasticsearch log store or forward logs to external log stores. The default log store is optimized and tested for short-term storage.

- **visualization** - This is the UI component you can use to view logs, graphs, charts, and so forth. The current implementation is Kibana.

For more information on OpenShift Logging, see the [OpenShift Logging documentation](#).

### 13.9.3. About Telemetry

Telemetry sends a carefully chosen subset of the cluster monitoring metrics to Red Hat. The Telemeter Client fetches the metrics values every four minutes and thirty seconds and uploads the data to Red Hat. These metrics are described in this document.

This stream of data is used by Red Hat to monitor the clusters in real-time and to react as necessary to problems that impact our customers. It also allows Red Hat to roll out OpenShift Container Platform upgrades to customers to minimize service impact and continuously improve the upgrade experience.

This debugging information is available to Red Hat Support and Engineering teams with the same restrictions as accessing data reported through support cases. All connected cluster information is used by Red Hat to help make OpenShift Container Platform better and more intuitive to use.

### 13.9.3.1. Information collected by Telemetry

The following information is collected by Telemetry:

- The unique random identifier that is generated during an installation

- Version information, including the OpenShift Container Platform cluster version and installed update details that are used to determine update version availability

- Update information, including the number of updates available per cluster, the channel and image repository used for an update, update progress information, and the number of errors that occur in an update

- The name of the provider platform that OpenShift Container Platform is deployed on and the data center location
• Sizing information about clusters, machine types, and machines, including the number of CPU cores and the amount of RAM used for each
• The number of running virtual machine instances in a cluster
• The number of etcd members and the number of objects stored in the etcd cluster
• The OpenShift Container Platform framework components installed in a cluster and their condition and status
• Usage information about components, features, and extensions
• Usage details about Technology Previews and unsupported configurations
• Information about degraded software
• Information about nodes that are marked as NotReady
• Events for all namespaces listed as “related objects” for a degraded Operator
• Configuration details that help Red Hat Support to provide beneficial support for customers, including node configuration at the cloud infrastructure level, hostnames, IP addresses, Kubernetes pod names, namespaces, and services
• Information about the validity of certificates
• Number of application builds by build strategy type

Telemetry does not collect identifying information such as user names or passwords. Red Hat does not intend to collect personal information. If Red Hat discovers that personal information has been inadvertently received, Red Hat will delete such information. To the extent that any telemetry data constitutes personal data, please refer to the Red Hat Privacy Statement for more information about Red Hat’s privacy practices.

13.9.4. CLI troubleshooting and debugging commands

For a list of the oc client troubleshooting and debugging commands, see the OpenShift Container Platform CLI tools documentation.

13.10. PROMETHEUS QUERIES FOR VIRTUAL RESOURCES

OpenShift Virtualization provides metrics for monitoring how infrastructure resources are consumed in the cluster. The metrics cover the following resources:

• vCPU
• Network
• Storage
• Guest memory swapping

Use the OpenShift Container Platform monitoring dashboard to query virtualization metrics.

13.10.1. Prerequisites
To use the vCPU metric, the `schedstats=enable` kernel argument must be applied to the `MachineConfig` object. This kernel argument enables scheduler statistics used for debugging and performance tuning and adds a minor additional load to the scheduler. See the OpenShift Container Platform machine configuration tasks documentation for more information on applying a kernel argument.

For guest memory swapping queries to return data, memory swapping must be enabled on the virtual guests.

### 13.10.2. Querying metrics

The OpenShift Container Platform monitoring dashboard enables you to run Prometheus Query Language (PromQL) queries to examine metrics visualized on a plot. This functionality provides information about the state of a cluster and any user-defined workloads that you are monitoring.

As a cluster administrator, you can query metrics for all core OpenShift Container Platform and user-defined projects.

As a developer, you must specify a project name when querying metrics. You must have the required privileges to view metrics for the selected project.

#### 13.10.2.1. Querying metrics for all projects as a cluster administrator

As a cluster administrator or as a user with view permissions for all projects, you can access metrics for all default OpenShift Container Platform and user-defined projects in the Metrics UI.

**NOTE**

Only cluster administrators have access to the third-party UIs provided with OpenShift Container Platform Monitoring.

**Prerequisites**

- You have access to the cluster as a user with the `cluster-admin` role or with view permissions for all projects.
- You have installed the OpenShift CLI (`oc`).

**Procedure**

1. In the Administrator perspective within the OpenShift Container Platform web console, select **Observe → Metrics**.

2. Select **Insert Metric at Cursor** to view a list of predefined queries.

3. To create a custom query, add your Prometheus Query Language (PromQL) query to the **Expression** field.

4. To add multiple queries, select **Add Query**.

5. To delete a query, select **next to the query, then choose Delete query**.
6. To disable a query from being run, select next to the query and choose *Disable query*.

7. Select *Run Queries* to run the queries that you have created. The metrics from the queries are visualized on the plot. If a query is invalid, the UI shows an error message.

**NOTE**

Queries that operate on large amounts of data might time out or overload the browser when drawing time series graphs. To avoid this, select *Hide graph* and calibrate your query using only the metrics table. Then, after finding a feasible query, enable the plot to draw the graphs.

8. Optional: The page URL now contains the queries you ran. To use this set of queries again in the future, save this URL.

**Additional resources**

- See the [Prometheus query documentation](#) for more information about creating PromQL queries.

### 13.10.2.2. Querying metrics for user-defined projects as a developer

You can access metrics for a user-defined project as a developer or as a user with view permissions for the project.

In the *Developer* perspective, the Metrics UI includes some predefined CPU, memory, bandwidth, and network packet queries for the selected project. You can also run custom Prometheus Query Language (PromQL) queries for CPU, memory, bandwidth, network packet and application metrics for the project.

**NOTE**

Developers can only use the *Developer* perspective and not the *Administrator* perspective. As a developer, you can only query metrics for one project at a time. Developers cannot access the third-party UIs provided with OpenShift Container Platform monitoring that are for core platform components. Instead, use the Metrics UI for your user-defined project.

**Prerequisites**

- You have access to the cluster as a developer or as a user with view permissions for the project that you are viewing metrics for.
- You have enabled monitoring for user-defined projects.
- You have deployed a service in a user-defined project.
- You have created a *ServiceMonitor* custom resource definition (CRD) for the service to define how the service is monitored.

**Procedure**

1. From the *Developer* perspective in the OpenShift Container Platform web console, select *Observe → Metrics*. 
2. Select the project that you want to view metrics for in the **Project** list.

3. Choose a query from the **Select Query** list, or run a custom Prometheus Query Language (PromQL) query by selecting **Show PromQL**.

**NOTE**

In the **Developer** perspective, you can only run one query at a time.

Additional resources

- See the Prometheus query documentation for more information about creating Prometheus queries.

### 13.10.3. Virtualization metrics

The following metric descriptions include example Prometheus Query Language (PromQL) queries. These metrics are not an API and might change between versions.

**NOTE**

The following examples use **topk** queries that specify a time period. If virtual machines are deleted during that time period, they can still appear in the query output.

#### 13.10.3.1. vCPU metrics

The following query can identify virtual machines that are waiting for Input/Output (I/O):

- **kubevent_vmi_vcpu_wait_seconds**
  
  Returns the wait time (in seconds) for a virtual machine's vCPU.

  A value above '0' means that the vCPU wants to run, but the host scheduler cannot run it yet. This inability to run indicates that there is an issue with I/O.

  **NOTE**

  To query the vCPU metric, the **schedstats=enable** kernel argument must first be applied to the **MachineConfig** object. This kernel argument enables scheduler statistics used for debugging and performance tuning and adds a minor additional load to the scheduler.

**Example vCPU wait time query**

```
| topk(3, sum by (name, namespace) (rate(kubevent_vmi_vcpu_wait_seconds[6m]))) > 0 |
```

This query returns the top 3 VMs waiting for I/O at every given moment over a six-minute time period.

#### 13.10.3.2. Network metrics

The following queries can identify virtual machines that are saturating the network:

- **kubevent_vmi_network_receive_bytes_total**
Returns the total amount of traffic received (in bytes) on the virtual machine’s network.

**kubevirt_vmi_network_transmit_bytes_total**

Returns the total amount of traffic transmitted (in bytes) on the virtual machine’s network.

**Example network traffic query**

```plaintext
topk(3, sum by (name, namespace) (rate(kubevirt_vmi_network_receive_bytes_total[6m])) + sum by (name, namespace) (rate(kubevirt_vmi_network_transmit_bytes_total[6m]))) > 0
```

1. This query returns the top 3 VMs transmitting the most network traffic at every given moment over a six-minute time period.

13.10.3.3. Storage metrics

13.10.3.3.1. Storage-related traffic

The following queries can identify VMs that are writing large amounts of data:

**kubevirt_vmi_storage_read_traffic_bytes_total**

Returns the total amount (in bytes) of the virtual machine’s storage-related traffic.

**kubevirt_vmi_storage_write_traffic_bytes_total**

Returns the total amount of storage writes (in bytes) of the virtual machine’s storage-related traffic.

**Example storage-related traffic query**

```plaintext
topk(3, sum by (name, namespace) (rate(kubevirt_vmi_storage_read_traffic_bytes_total[6m])) + sum by (name, namespace) (rate(kubevirt_vmi_storage_write_traffic_bytes_total[6m]))) > 0
```

1. This query returns the top 3 VMs performing the most storage traffic at every given moment over a six-minute time period.

13.10.3.3.2. I/O performance

The following queries can determine the I/O performance of storage devices:

**kubevirt_vmi_storage_iops_read_total**

Returns the amount of write I/O operations the virtual machine is performing per second.

**kubevirt_vmi_storage_iops_write_total**

Returns the amount of read I/O operations the virtual machine is performing per second.

**Example I/O performance query**

```plaintext
topk(3, sum by (name, namespace) (rate(kubevirt_vmi_storage_iops_read_total[6m])) + sum by (name, namespace) (rate(kubevirt_vmi_storage_iops_write_total[6m]))) > 0
```

1. This query returns the top 3 VMs performing the most I/O operations per second at every given moment over a six-minute time period.
13.10.3.4. Guest memory swapping metrics

The following queries can identify which swap-enabled guests are performing the most memory swapping:

**kubevirt_vmi_memory_swap_in_traffic_bytes_total**

Returns the total amount (in bytes) of memory the virtual guest is swapping in.

**kubevirt_vmi_memory_swap_out_traffic_bytes_total**

Returns the total amount (in bytes) of memory the virtual guest is swapping out.

**Example memory swapping query**

```
topk(3, sum by (name, namespace) (rate(kubevirt_vmi_memory_swap_in_traffic_bytes_total[6m])) + 
    sum by (name, namespace) (rate(kubevirt_vmi_memory_swap_out_traffic_bytes_total[6m]))) > 0
```

This query returns the top 3 VMs where the guest is performing the most memory swapping at every given moment over a six-minute time period.

**NOTE**

Memory swapping indicates that the virtual machine is under memory pressure. Increasing the memory allocation of the virtual machine can mitigate this issue.

13.10.4. Additional resources

- Monitoring overview

13.11. EXPOSING CUSTOM METRICS FOR VIRTUAL MACHINES

OpenShift Container Platform includes a pre-configured, pre-installed, and self-updating monitoring stack that provides monitoring for core platform components. This monitoring stack is based on the Prometheus monitoring system. Prometheus is a time-series database and a rule evaluation engine for metrics.

In addition to using the OpenShift Container Platform monitoring stack, you can enable monitoring for user-defined projects by using the CLI and query custom metrics that are exposed for virtual machines through the **node-exporter** service.

13.11.1. Configuring the node exporter service

The node-exporter agent is deployed on every virtual machine in the cluster from which you want to collect metrics. Configure the node-exporter agent as a service to expose internal metrics and processes that are associated with virtual machines.

**Prerequisites**

- Install the OpenShift Container Platform CLI **oc**.
- Log in to the cluster as a user with **cluster-admin** privileges.
- Create the **cluster-monitoring-config** ConfigMap object in the **openshift-monitoring** project.
Configure the user-workload-monitoring-config ConfigMap object in the openshift-user-workload-monitoring project by setting enableUserWorkload to true.

Procedure

1. Create the Service YAML file. In the following example, the file is called node-exporter-service.yaml.

   ```yaml
   kind: Service
   apiVersion: v1
   metadata:
     name: node-exporter-service
     namespace: dynamation
   labels:
     servicetype: metrics
   spec:
     ports:
     - name: exmet
       protocol: TCP
       port: 9100
       targetPort: 9100
     type: ClusterIP
     selector:
       monitor: metrics
   ```

   1. The node-exporter service that exposes the metrics from the virtual machines.
   2. The namespace where the service is created.
   3. The label for the service. The ServiceMonitor uses this label to match this service.
   4. The name given to the port that exposes metrics on port 9100 for the ClusterIP service.
   5. The target port used by node-exporter-service to listen for requests.
   6. The TCP port number of the virtual machine that is configured with the monitor label.
   7. The label used to match the virtual machine’s pods. In this example, any virtual machine’s pod with the label monitor and a value of metrics will be matched.

2. Create the node-exporter service:

   ```bash
   $ oc create -f node-exporter-service.yaml
   ```

13.11.2. Configuring a virtual machine with the node exporter service

Download the node-exporter file on to the virtual machine. Then, create a systemd service that runs the node-exporter service when the virtual machine boots.

Prerequisites

- The pods for the component are running in the openshift-user-workload-monitoring project.
- Grant the **monitoring-edit** role to users who need to monitor this user-defined project.

**Procedure**

1. Log on to the virtual machine.

2. Download the **node-exporter** file on to the virtual machine by using the directory path that applies to the version of **node-exporter** file.

   ```
   $ wget https://github.com/prometheus/node_exporter/releases/download/v1.3.1/node_exporter-1.3.1.linux-amd64.tar.gz
   ```

3. Extract the executable and place it in the `/usr/bin` directory.

   ```
   $ sudo tar xvf node_exporter-1.3.1.linux-amd64.tar.gz \
   --directory /usr/bin --strip 1 "*/node_exporter"
   ```

4. Create a **node_exporter.service** file in this directory path: `/etc/systemd/system`. This **systemd** service file runs the node-exporter service when the virtual machine reboots.

   ```
   [Unit]
   Description=Prometheus Metrics Exporter
   After=network.target
   StartLimitIntervalSec=0
   
   [Service]
   Type=simple
   Restart=always
   RestartSec=1
   User=root
   ExecStart=/usr/bin/node_exporter
   
   [Install]
   WantedBy=multi-user.target
   ```

5. Enable and start the **systemd** service.

   ```
   $ sudo systemctl enable node_exporter.service
   $ sudo systemctl start node_exporter.service
   ```

**Verification**

- Verify that the node-exporter agent is reporting metrics from the virtual machine.

   ```
   $ curl http://localhost:9100/metrics
   ```

**Example output**

```
go_gc_duration_seconds{quantile="0"} 1.5244e-05
go_gc_duration_seconds{quantile="0.25"} 3.0449e-05
go_gc_duration_seconds{quantile="0.5"} 3.7913e-05
```
13.11.3. Creating a custom monitoring label for virtual machines

To enable queries to multiple virtual machines from a single service, add a custom label in the virtual machine’s YAML file.

Prerequisites

- Install the OpenShift Container Platform CLI oc.
- Log in as a user with cluster-admin privileges.
- Access to the web console for stop and restart a virtual machine.

Procedure

1. Edit the template spec of your virtual machine configuration file. In this example, the label monitor has the value metrics.

```
spec:
template:
  metadata:
    labels:
      monitor: metrics
```

2. Stop and restart the virtual machine to create a new pod with the label name given to the monitor label.

13.11.3.1. Querying the node-exporter service for metrics

Metrics are exposed for virtual machines through an HTTP service endpoint under the /metrics canonical name. When you query for metrics, Prometheus directly scrapes the metrics from the metrics endpoint exposed by the virtual machines and presents these metrics for viewing.

Prerequisites

- You have access to the cluster as a user with cluster-admin privileges or the monitoring-edit role.
- You have enabled monitoring for the user-defined project by configuring the node-exporter service.

Procedure

1. Obtain the HTTP service endpoint by specifying the namespace for the service:

```
$ oc get service -n <namespace> <node-exporter-service>
```

2. To list all available metrics for the node-exporter service, query the metrics resource.

```
$ curl http://<172.30.226.162:9100>/metrics | grep -vE "^#|^$"
```

Example output

```
node_arp_entries{device="eth0"} 1
```
13.11.4. Creating a ServiceMonitor resource for the node exporter service

You can use a Prometheus client library and scrape metrics from the /metrics endpoint to access and view the metrics exposed by the node-exporter service. Use a ServiceMonitor custom resource definition (CRD) to monitor the node exporter service.

**Prerequisites**
You have access to the cluster as a user with `cluster-admin` privileges or the `monitoring-edit` role.

You have enabled monitoring for the user-defined project by configuring the node-exporter service.

**Procedure**

1. Create a YAML file for the `ServiceMonitor` resource configuration. In this example, the service monitor matches any service with the label `metrics` and queries the `exmet` port every 30 seconds.

   ```yaml
   apiVersion: monitoring.coreos.com/v1
   kind: ServiceMonitor
   metadata:
     labels:
       k8s-app: node-exporter-metrics-monitor
       name: node-exporter-metrics-monitor
       namespace: dynamation
   spec:
     endpoints:
     - interval: 30s
       port: exmet
       scheme: http
     selector:
       matchLabels:
         servicetype: metrics
   ```

   - **1** The name of the `ServiceMonitor`.
   - **2** The namespace where the `ServiceMonitor` is created.
   - **3** The interval at which the port will be queried.
   - **4** The name of the port that is queried every 30 seconds.

2. Create the `ServiceMonitor` configuration for the node-exporter service.

   ```bash
   $ oc create -f node-exporter-metrics-monitor.yaml
   ```

**13.11.4.1. Accessing the node exporter service outside the cluster**

You can access the node-exporter service outside the cluster and view the exposed metrics.

**Prerequisites**

- You have access to the cluster as a user with `cluster-admin` privileges or the `monitoring-edit` role.

- You have enabled monitoring for the user-defined project by configuring the node-exporter service.

**Procedure**
1. Expose the node-exporter service.

   $ oc expose service -n <namespace> <node_exporter_service_name>

2. Obtain the FQDN (Fully Qualified Domain Name) for the route.

   $ oc get route -o=custom-columns=NAME:.metadata.name,DNS:.spec.host

   **Example output**

<table>
<thead>
<tr>
<th>NAME</th>
<th>DNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>node-exporter-service</td>
<td>node-exporter-service-dynamation.apps.cluster.example.org</td>
</tr>
</tbody>
</table>

3. Use the `curl` command to display metrics for the node-exporter service.

   $ curl -s http://node-exporter-service-dynamation.apps.cluster.example.org/metrics

   **Example output**

   `go_gc_duration_seconds{quantile="0"} 1.5382e-05`
   `go_gc_duration_seconds{quantile="0.25"} 3.1163e-05`
   `go_gc_duration_seconds{quantile="0.5"} 3.8546e-05`
   `go_gc_duration_seconds{quantile="0.75"} 4.9139e-05`
   `go_gc_duration_seconds{quantile="1"} 0.000189423`

### 13.11.5. Additional resources

- Configuring the monitoring stack
- Enabling monitoring for user-defined projects
- Managing metrics
- Reviewing monitoring dashboards
- Monitoring application health by using health checks
- Creating and using config maps
- Controlling virtual machine states

### 13.12. OPENSHIFT VIRTUALIZATION CRITICAL ALERTS
OpenShift Virtualization has alerts that inform you when a problem occurs. Critical alerts require immediate attention.

Each alert has a corresponding description of the problem, a reason for why the alert is occurring, a troubleshooting process to diagnose the source of the problem, and steps for resolving the alert.

13.12.1. Network alerts

Network alerts provide information about problems for the OpenShift Virtualization Network Operator.

13.12.1.1. KubeMacPoolDown alert

Description
The KubeMacPool component allocates MAC addresses and prevents MAC address conflicts.

Reason
If the KubeMacPool-manager pod is down, then the creation of VirtualMachine objects fails.

Troubleshoot

1. Determine the Kubemacpool-manager pod namespace and name.

   $ export KMP_NAMESPACE="$(oc get pod -A --no-headers -l control-plane=mac-controller-manager | awk '{print $1}')"

   $ export KMP_NAME="$(oc get pod -A --no-headers -l control-plane=mac-controller-manager | awk '{print $2}')"

2. Check the Kubemacpool-manager pod description and logs to determine the source of the problem.

   $ oc describe pod -n $KMP_NAMESPACE $KMP_NAME

   $ oc logs -n $KMP_NAMESPACE $KMP_NAME

Resolution

Open a support issue and provide the information gathered in the troubleshooting process.

13.12.2. SSP alerts
SSP alerts provide information about problems for the OpenShift Virtualization SSP Operator.

13.12.2.1. SSPFailingToReconcile alert

Description
The SSP Operator’s pod is up, but the pod’s reconcile cycle consistently fails. This failure includes failure to update the resources for which it is responsible, failure to deploy the template validator, or failure to deploy or update the common templates.

Reason
If the SSP Operator fails to reconcile, then the deployment of dependent components fails, reconciliation of component changes fails, or both. Additionally, the updates to the common templates and template validator reset and fail.

Troubleshoot
1. Check the ssp-operator pod’s logs for errors:
   
   ```
   $ export NAMESPACE="$(oc get deployment -A | grep ssp-operator | awk '{print $1}')"
   $ oc -n $NAMESPACE describe pods -l control-plane=ssp-operator
   $ oc -n $NAMESPACE logs --tail=-1 -l control-plane=ssp-operator
   ```

2. Verify that the template validator is up. If the template validator is not up, then check the pod’s logs for errors.

   ```
   $ export NAMESPACE="$(oc get deployment -A | grep ssp-operator | awk '{print $1}')"
   $ oc -n $NAMESPACE get pods -l name=virt-template-validator
   $ oc -n $NAMESPACE describe pods -l name=virt-template-validator
   $ oc -n $NAMESPACE logs --tail=-1 -l name=virt-template-validator
   ```

Resolution
Open a support issue and provide the information gathered in the troubleshooting process.

13.12.2.2. SSPOperatorDown alert

Description
The SSP Operator deploys and reconciles the common templates and the template validator.

Reason
If the SSP Operator is down, then the deployment of dependent components fails, reconciliation of component changes fails, or both. Additionally, the updates to the common template and template validator reset and fail.
Troubleshoot

1. Check ssp-operator’s pod namespace:

   $ export NAMESPACE="$(oc get deployment -A | grep ssp-operator | awk '{print $1}'))"

   $ oc -n $NAMESPACE get pods -l control-plane=ssp-operator

2. Verify that the ssp-operator’s pod is currently down.

   $ oc -n $NAMESPACE get pods -l control-plane=ssp-operator

3. Check the ssp-operator’s pod description and logs.

   $ oc -n $NAMESPACE describe pods -l control-plane=ssp-operator

   $ oc -n $NAMESPACE logs --tail=-1 -l control-plane=ssp-operator

Resolution

Open a support issue and provide the information gathered in the troubleshooting process.

13.12.2.3. SSPTemplateValidatorDown alert

Description

The template validator validates that virtual machines (VMs) do not violate their assigned templates.

Reason

If every template validator pod is down, then the template validator fails to validate VMs against their assigned templates.

Troubleshoot

1. Check the namespaces of the ssp-operator pods and the virt-template-validator pods.

   $ export NAMESPACE_ SSP="$(oc get deployment -A | grep ssp-operator | awk '{print $1}'))"

   $ export NAMESPACE="$(oc get deployment -A | grep virt-template-validator | awk '{print $1}'))"

2. Verify that the virt-template-validator’s pod is currently down.

   $ oc -n $NAMESPACE get pods -l name=virt-template-validator

3. Check the pod description and logs of the ssp-operator and the virt-template-validator.

   $ oc -n $NAMESPACE_ SSP describe pods -l name=ssp-operator

   $ oc -n $NAMESPACE_ SSP logs --tail=-1 -l name=ssp-operator

   $ oc -n $NAMESPACE describe pods -l name=virt-template-validator
Resolution
Open a support issue and provide the information gathered in the troubleshooting process.

13.12.3. Virt alerts
Virt alerts provide information about problems for the OpenShift Virtualization Virt Operator.

13.12.3.1. NoLeadingVirtOperator alert

Description
In the past 10 minutes, no virt-operator pod holds the leader lease, despite one or more virt-operator pods being in Ready state. The alert suggests no operating virt-operator pod exists.

Reason
The virt-operator is the first Kubernetes Operator active in a OpenShift Container Platform cluster. Its primary responsibilities are:

- Installation
- Live-update
- Live-upgrade of a cluster
- Monitoring the lifecycle of top-level controllers such as virt-controller, virt-handler, and virt-launcher
- Managing the reconciliation of top-level controllers

In addition, the virt-operator is responsible for cluster-wide tasks such as certificate rotation and some infrastructure management.

The virt-operator deployment has a default replica of two pods with one leader pod holding a leader lease, indicating an operating virt-operator pod.

This alert indicates a failure at the cluster level. Critical cluster-wide management functionalities such as certification rotation, upgrade, and reconciliation of controllers may be temporarily unavailable.

Troubleshoot
Determine a virt-operator pod’s leader status from the pod logs. The log messages containing Started leading and acquire leader indicate the leader status of a given virt-operator pod.

Additionally, always check if there are any running virt-operator pods and the pods' statuses with these commands:

```
$ export NAMESPACE="$(oc kubectl -A -o custom-columns="":.metadata.namespace")"

$ oc -n $NAMESPACE get pods -l kubevirt.io=virt-operator

$ oc -n $NAMESPACE logs <pod-name>
```

OpenShift Container Platform 4.10 Virtualization
Resolution

There are several reasons for no virt-operator pod holding the leader lease, despite one or more virt-operator pods being in **Ready** state. Identify the root cause and take appropriate action.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

### 13.12.3.2. NoReadyVirtController alert

**Description**

The virt-controller monitors virtual machine instances (VMIs). The virt-controller also manages the associated pods by creating and managing the lifecycle of the pods associated with the VMI objects.

A VMI object always associates with a pod during its lifetime. However, the pod instance can change over time because of VMI migration.

This alert occurs when detection of no ready virt-controllers occurs for five minutes.

**Reason**

If the virt-controller fails, then VM lifecycle management completely fails. Lifecycle management tasks include launching a new VMI or shutting down an existing VMI.
Troubleshoot

1. Check the vdeployment status of the virt-controller for available replicas and conditions.

   $ oc -n $NAMESPACE get deployment virt-controller -o yaml

2. Check if the virt-controller pods exist and check their statuses.

   get pods -n $NAMESPACE |grep virt-controller

3. Check the virt-controller pods’ events.

   $ oc -n $NAMESPACE describe pods <virt-controller pod>

4. Check the virt-controller pods’ logs.

   $ oc -n $NAMESPACE logs <virt-controller pod>

5. Check if there are issues with the nodes, such as if the nodes are in a NotReady state.

   $ oc get nodes

Resolution

There are several reasons for no virt-controller pods being in a Ready state. Identify the root cause and take appropriate action.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.3. NoReadyVirtOperator alert

Description

No detection of a virt-operator pod in the Ready state occurs in the past 10 minutes. The virt-operator deployment has a default replica of two pods.

Reason

The virt-operator is the first Kubernetes Operator active in an OpenShift Container Platform cluster. Its primary responsibilities are:

- Installation
- Live-update
- Live-upgrade of a cluster
- Monitoring the lifecycle of top-level controllers such as virt-controller, virt-handler, and virt-launcher
- Managing the reconciliation of top-level controllers

In addition, the virt-operator is responsible for cluster-wide tasks such as certificate rotation and some infrastructure management.
NOTE

Virt-operator is not directly responsible for virtual machines in the cluster. Virt-operator’s unavailability does not affect the custom workloads.

This alert indicates a failure at the cluster level. Critical cluster-wide management functionalities such as certification rotation, upgrade, and reconciliation of controllers are temporarily unavailable.

Troubleshoot

1. Check the deployment status of the virt-operator for available replicas and conditions.
   
   $ oc -n $NAMESPACE get deployment virt-operator -o yaml

2. Check the virt-controller pods’ events.
   
   $ oc -n $NAMESPACE describe pods <virt-operator pod>

3. Check the virt-operator pods’ logs.
   
   $ oc -n $NAMESPACE logs <virt-operator pod>

4. Check if there are issues with the nodes for the control plane and masters, such as if they are in a NotReady state.
   
   $ oc get nodes

Resolution

There are several reasons for no virt-operator pods being in a Ready state. Identify the root cause and take appropriate action.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.4. VirtAPIDown alert

Description

All OpenShift Container Platform API servers are down.

Reason

If all OpenShift Container Platform API servers are down, then no API calls for OpenShift Container Platform entities occur.

Troubleshoot

1. Modify the environment variable NAMESPACE.
   
   $ export NAMESPACE="$(oc get kubevirt -A -o custom-columns="":.metadata.namespace)"

2. Verify if there are any running virt-api pods.
   
   $ oc -n $NAMESPACE get pods -l kubevirt.io=virt-api
3. View the pods' logs using `oc logs` and the pods' statuses using `oc describe`.

4. Check the status of the virt-api deployment. Use these commands to learn about related events and show if there are any issues with pulling an image, a crashing pod, or other similar problems.

   ```
   $ oc -n $NAMESPACE get deployment virt-api -o yaml
   $ oc -n $NAMESPACE describe deployment virt-api
   ```

5. Check if there are issues with the nodes, such as if the nodes are in a **NotReady** state.

   ```
   $ oc get nodes
   ```

**Resolution**

Virt-api pods can be down for several reasons. Identify the root cause and take appropriate action.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

**13.12.3.5. VirtApiRESTErrorsBurst alert**

**Description**

More than 80% of the REST calls fail in virt-api in the last five minutes.

**Reason**

A very high rate of failed REST calls to virt-api causes slow response, slow execution of API calls, or even complete dismissal of API calls.

**Troubleshoot**

1. Modify the environment variable **NAMESPACE**.

   ```
   $ export NAMESPACE="$(oc get kubevirt -A -o custom-columns="":.metadata.namespace")"
   ```

2. Check to see how many running virt-api pods exist.

   ```
   $ oc -n $NAMESPACE get pods -l kubevirt.io=virt-api
   ```

3. View the pods' logs using `oc logs` and the pods' statuses using `oc describe`.

4. Check the status of the virt-api deployment to find out more information. These commands provide the associated events and show if there are any issues with pulling an image or a crashing pod.

   ```
   $ oc -n $NAMESPACE get deployment virt-api -o yaml
   $ oc -n $NAMESPACE describe deployment virt-api
   ```

5. Check if there are issues with the nodes, such as if the nodes are overloaded or not in a **NotReady** state.

   ```
   $ oc get nodes
   ```
Resolution
There are several reasons for a high rate of failed REST calls. Identify the root cause and take appropriate action.

- Node resource exhaustion
- Not enough memory on the cluster
- Nodes are down
- The API server overloads, such as when the scheduler is not 100% available)
- Networking issues

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.6. VirtControllerDown alert

Description
If no detection of virt-controllers occurs in the past five minutes, then virt-controller deployment has a default replica of two pods.

Reason
If the virt-controller fails, then VM lifecycle management tasks, such as launching a new VMI or shutting down an existing VMI, completely fail.

Troubleshoot
1. Modify the environment variable $NAMESPACE$.

   ```bash
   $ export NAMESPACE="$(oc get kubevirt -A -o custom-columns="":.metadata.namespace)"
   ```

2. Check the status of the virt-controller deployment.

   ```bash
   $ oc get deployment -n $NAMESPACE virt-controller -o yaml
   ```

3. Check the virt-controller pods’ events.

   ```bash
   $ oc -n $NAMESPACE describe pods <virt-controller pod>
   ```

4. Check the virt-controller pods’ logs.

   ```bash
   $ oc -n $NAMESPACE logs <virt-controller pod>
   ```

5. Check the manager pod’s logs to determine why creating the virt-controller pods fails.

   ```bash
   $ oc get logs <virt-controller-pod>
   ```

An example of a virt-controller pod name in the logs is virt-controller-7888c64d66-dzc9p. However, there may be several pods that run virt-controller.
Resolution
There are several known reasons why the detection of no running virt-controller occurs. Identify the root cause from the list of possible reasons and take appropriate action.

- Node resource exhaustion
- Not enough memory on the cluster
- Nodes are down
- The API server overloads, such as when the scheduler is not 100% available
- Networking issues

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.7. VirtControllerRESTErrorsBurst alert

Description
More than 80% of the REST calls failed in virt-controller in the last five minutes.

Reason
Virt-controller has potentially fully lost connectivity to the API server. This loss does not affect running workloads, but propagation of status updates and actions like migrations cannot occur.

Troubleshoot
There are two common error types associated with virt-controller REST call failure:

- The API server overloads, causing timeouts. Check the API server metrics and details like response times and overall calls.
- The virt-controller pod cannot reach the API server. Common causes are:
  - DNS issues on the node
  - Networking connectivity issues

Resolution
Check the virt-controller logs to determine if the virt-controller pod cannot connect to the API server at all. If so, delete the pod to force a restart.

Additionally, verify if node resource exhaustion or not having enough memory on the cluster is causing the connection failure.

The issue normally relates to DNS or CNI issues outside of the scope of this alert.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.8. VirtHandlerRESTErrorsBurst alert

Description
More than 80% of the REST calls failed in virt-handler in the last five minutes.
Reason
Virt-handler lost the connection to the API server. Running workloads on the affected node still run, but status updates cannot propagate and actions such as migrations cannot occur.

Troubleshoot
There are two common error types associated with virt-operator REST call failure:

- The API server overloads, causing timeouts. Check the API server metrics and details like response times and overall calls.
- The virt-operator pod cannot reach the API server. Common causes are:
  - DNS issues on the node
  - Networking connectivity issues

Resolution
If the virt-handler cannot connect to the API server, delete the pod to force a restart. The issue normally relates to DNS or CNI issues outside of the scope of this alert. Identify the root cause and take appropriate action.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.9. VirtOperatorDown alert

Description
This alert occurs when no virt-operator pod is in the Running state in the past 10 minutes. The virt-operator deployment has a default replica of two pods.

Reason
The virt-operator is the first Kubernetes Operator active in an OpenShift Container Platform cluster. Its primary responsibilities are:

- Installation
- Live-update
- Live-upgrade of a cluster
- Monitoring the lifecycle of top-level controllers such as virt-controller, virt-handler, and virt-launcher
- Managing the reconciliation of top-level controllers

In addition, the virt-operator is responsible for cluster-wide tasks such as certificate rotation and some infrastructure management.

NOTE
The virt-operator is not directly responsible for virtual machines in the cluster. The virt-operator’s unavailability does not affect the custom workloads.
This alert indicates a failure at the cluster level. Critical cluster-wide management functionalities such as certification rotation, upgrade, and reconciliation of controllers are temporarily unavailable.

Troubleshoot

1. Modify the environment variable `NAMESPACE`.

   ```bash
   $ export NAMESPACE=$(oc get kubevirt -A -o custom-columns="":.metadata.namespace")
   ```

2. Check the status of the virt-operator deployment.

   ```bash
   $ oc get deployment -n $NAMESPACE virt-operator -o yaml
   ```

3. Check the virt-operator pods’ events.

   ```bash
   $ oc -n $NAMESPACE describe pods <virt-operator pod>
   ```

4. Check the virt-operator pods’ logs.

   ```bash
   $ oc -n $NAMESPACE logs <virt-operator pod>
   ```

5. Check the manager pod’s logs to determine why creating the virt-operator pods fails.

   ```bash
   $ oc get logs <virt-operator-pod>
   ```

An example of a virt-operator pod name in the logs is `virt-operator-7888c64d66-dzc9p`. However, there may be several pods that run virt-operator.

Resolution

There are several known reasons why the detection of no running virt-operator occurs. Identify the root cause from the list of possible reasons and take appropriate action.

- Node resource exhaustion
- Not enough memory on the cluster
- Nodes are down
- The API server overloads, such as when the scheduler is not 100% available
- Networking issues

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.3.10. VirtOperatorRESTErrorsBurst alert

Description

More than 80% of the REST calls failed in virt-operator in the last five minutes.

Reason
Virt-operator lost the connection to the API server. Cluster-level actions such as upgrading and controller reconciliation do not function. There is no effect to customer workloads such as VMs and VMIs.

Troubleshoot

There are two common error types associated with virt-operator REST call failure:

- The API server overloads, causing timeouts. Check the API server metrics and details, such as response times and overall calls.

- The virt-operator pod cannot reach the API server. Common causes are network connectivity problems and DNS issues on the node. Check the virt-operator logs to verify that the pod can connect to the API server at all.

```
$ export NAMESPACE="$(oc get kubevirt -A -o custom-columns="":.metadata.namespace)"
$ oc -n $NAMESPACE get pods -l kubevirt.io=virt-operator
$ oc -n $NAMESPACE logs <pod-name>
$ oc -n $NAMESPACE describe pod <pod-name>
```

Resolution

If the virt-operator cannot connect to the API server, delete the pod to force a restart. The issue normally relates to DNS or CNI issues outside of the scope of this alert. Identify the root cause and take appropriate action.

Otherwise, open a support issue and provide the information gathered in the troubleshooting process.

13.12.4. Additional resources

- Getting support

13.13. COLLECTING OPENSIFT VIRTUALIZATION DATA FOR RED HAT SUPPORT

When opening a support case, it is helpful to provide debugging information about your cluster to Red Hat Support.

The must-gather tool enables you to collect diagnostic information about your OpenShift Container Platform cluster, including virtual machines and other data related to OpenShift Virtualization.

For prompt support, supply diagnostic information for both OpenShift Container Platform and OpenShift Virtualization.

13.13.1. About the must-gather tool

The oc adm must-gather CLI command collects the information from your cluster that is most likely needed for debugging issues, including:

- Resource definitions
Service logs

By default, the `oc adm must-gather` command uses the default plug-in image and writes into `/must-gather.local`.

Alternatively, you can collect specific information by running the command with the appropriate arguments as described in the following sections:

- To collect data related to one or more specific features, use the `--image` argument with an image, as listed in a following section.
  For example:

  ```
  $ oc adm must-gather --image=registry.redhat.io/container-native-virtualization/cnv-must-gather-rhel8:v4.10.0
  ```

- To collect the audit logs, use the `-- /usr/bin/gather_audit_logs` argument, as described in a following section.
  For example:

  ```
  $ oc adm must-gather -- /usr/bin/gather_audit_logs
  ```

  **NOTE**
  
  Audit logs are not collected as part of the default set of information to reduce the size of the files.

When you run `oc adm must-gather`, a new pod with a random name is created in a new project on the cluster. The data is collected on that pod and saved in a new directory that starts with `must-gather.local`. This directory is created in the current working directory.

For example:

<table>
<thead>
<tr>
<th>NAMESPACE</th>
<th>NAME</th>
<th>READY</th>
<th>STATUS</th>
<th>RESTARTS</th>
<th>AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2/2</td>
<td>Running</td>
<td>0</td>
<td>72s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2/2</td>
<td>Running</td>
<td>0</td>
<td>72s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2/2</td>
<td>Running</td>
<td>0</td>
<td>72s</td>
</tr>
</tbody>
</table>

**13.13.2. About collecting OpenShift Virtualization data**

You can use the `oc adm must-gather` CLI command to collect information about your cluster, including features and objects associated with OpenShift Virtualization:

- The OpenShift Virtualization Operator namespaces (and child objects)
- All OpenShift Virtualization custom resource definitions (CRDs)
- All namespaces that contain virtual machines
- Basic virtual machine definitions

To collect OpenShift Virtualization data with `must-gather`, you must specify the OpenShift Virtualization image: `--image=registry.redhat.io/container-native-virtualization/cnv-must-gather-rhel8:v4.10.0`. 350
13.13.3. Gathering data about specific features

You can gather debugging information about specific features by using the `oc adm must-gather` CLI command with the `--image` or `--image-stream` argument. The `must-gather` tool supports multiple images, so you can gather data about more than one feature by running a single command.

NOTE

To collect the default `must-gather` data in addition to specific feature data, add the `--image-stream=openshift/must-gather` argument.

Prerequisites

- Access to the cluster as a user with the `cluster-admin` role.
- The OpenShift Container Platform CLI (`oc`) installed.

Procedure

1. Navigate to the directory where you want to store the `must-gather` data.

2. Run the `oc adm must-gather` command with one or more `--image` or `--image-stream` arguments. For example, the following command gathers both the default cluster data and information specific to OpenShift Virtualization:

   ```bash
   $ oc adm must-gather \
   --image-stream=openshift/must-gather \
   --image=registry.redhat.io/container-native-virtualization/cnv-must-gather-rhel8:v4.10.0
   $ oc adm must-gather --image=$(oc -n openshift-logging get deployment.apps/cluster-logging-operator -o jsonpath='{.spec.template.spec.containers[?(@.name == "cluster-logging-operator")].image}')
   ```

   1. The default OpenShift Container Platform `must-gather` image
   2. The `must-gather` image for OpenShift Virtualization

You can use the `must-gather` tool with additional arguments to gather data that is specifically related to OpenShift Logging and the Red Hat OpenShift Logging Operator in your cluster. For OpenShift Logging, run the following command:

   ```bash
   $ oc adm must-gather --image=$(oc -n openshift-logging get deployment.apps/cluster-logging-operator -o jsonpath='{.spec.template.spec.containers[?(@.name == "cluster-logging-operator")].image}')
   ```

Example 13.1. Example `must-gather` output for OpenShift Logging

```
├── cluster-logging
│   ├── clo
│   │   ├── cluster-logging-operator-74dd5994f-6ttgt
│   │   │   ├── clusterlogforwarder_cr
│   │   │   │   └── cr
│   │   │   └── csv
│   │   └── deployment
│   │       └── logforwarding_cr
│   │           └── collector
```
3. Create a compressed file from the must-gather directory that was just created in your working directory. For example, on a computer that uses a Linux operating system, run the following command:

```bash
$ tar cvaf must-gather.tar.gz must-gather.local.5421342344627712289/
```

Make sure to replace `must-gather-local.5421342344627712289/` with the actual directory name.

4. Attach the compressed file to your support case on the Red Hat Customer Portal.

### 13.13.4. must-gather tool usage for targeted VM data

When you use the **must-gather** CLI tool to collect OpenShift Virtualization data, the virtual machine (VM) information collected by default is limited to **VirtualMachine** and **VirtualMachineInstance** custom resources (CRs). You can request additional or targeted data by including parameters when you run the **must-gather** command. These parameters include environment variables and scripts.

#### Supported parameters

**Environment variables**

**NS=<namespace_name>**

Gather virtual machine information, including **virt-launcher** pod details, from the namespace that you specify. The **VirtualMachine** and **VirtualMachineInstance** CR data is collected for all namespaces.

**VM=<vm_name>**

Gather details about a particular virtual machine. To use this option, you must also specify a namespace by using the **NS** environment variable.

**PROS=<number_of_processes>**

Modify the maximum number of parallel processes that the **must-gather** tool uses. By default, the tool uses no more than five parallel processes.

**IMPORTANT**

Using too many parallel processes can cause performance issues. Increasing the maximum number of parallel processes is not recommended.
Scripts

Each script is only compatible with certain variable combinations.

**gather_vms_details**

Collect virtual machine log files, VM definitions, and namespaces (and their child objects) that belong to OpenShift Virtualization resources. If you use this parameter without specifying a namespace or VM, the **must-gather** tool collects this data for all VMs in the cluster. This script is compatible with all of the supported environment variables, but you must specify a namespace if you use the **VM** variable.

**gather**

Use the default **must-gather** script, which collects cluster data from all namespaces and includes only basic VM information. This script is only compatible with the **PROS** variable.

**gather_images**

Collect image and image stream custom resource information. This script is only compatible with the **PROS** variable.

**Usage**

To customize the data that **must-gather** collects, append a double dash (``--) to the command, followed by one or more compatible parameters. If you use any environment variables, you must specify a script.

The following options are valid:

- You can specify one script without using any environment variables.
- You can use one or more environment variables in any order, followed by one script.

**Syntax**

```
$ oc adm must-gather --image=registry.redhat.io/container-nativeirtualization/cnv-must-gather-rhel8:v4.10.0  
  -- <environment_variable_1> <environment_variable_2> <script_name>
```

**Examples**

- The following command collects extensive VM details for the **my-vm** VM in the **mynamespace** namespace:

  ```
  $ oc adm must-gather --image=registry.redhat.io/container-nativeirtualization/cnv-must-gather-rhel8:v4.10.0  
   -- NS=mynamespace VM=my-vm gather_vms_details
  ```

  **IMPORTANT**

  If you use the **VM** environment variable, you must also specify a namespace.

- The following command collects default **must-gather** information by using a maximum of three parallel processes:

  ```
  $ oc adm must-gather --image=registry.redhat.io/container-nativeirtualization/cnv-must-gather-rhel8:v4.10.0  
   -- PROS=3 gather
  ```

- The following command collects image and image stream information from the cluster:
$ oc adm must-gather --image=registry.redhat.io/container-nativeirtualization/cnv-must-gather-rhel8:v4.10.0 -- gather_images
CHAPTER 14. BACKUP AND RESTORE

14.1. BACKUP AND RESTORE OVERVIEW

As a cluster administrator, you back up and restore OpenShift Virtualization virtual machines (VMs) by using the OpenShift API for Data Protection (OADP).

IMPORTANT

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

For more information about the support scope of Red Hat Technology Preview features, see https://access.redhat.com/support/offerings/techpreview/.

You install the OADP Operator by using Operator Lifecycle Manager. The Operator installs Velero 1.7.

You create a Secret for the backup storage provider and then you install the Data Protection Application.

You back up VMs by creating a Backup custom resource (CR).

You restore the Backup CR by creating a Restore CR.

14.1.1. Additional resources

- OADP overview
- OADP features and plugins
- Troubleshooting

14.2. INSTALLING AND CONFIGURING OADP

As a cluster administrator, you install the OpenShift API for Data Protection (OADP) by installing the OADP Operator. The Operator installs Velero 1.7.

You create a default Secret for your backup storage provider and then you install the Data Protection Application.

14.2.1. Installing the OADP Operator

You install the OpenShift API for Data Protection (OADP) Operator on OpenShift Container Platform 4.10 by using Operator Lifecycle Manager (OLM).

The OADP Operator installs Velero 1.7.

Prerequisites

- You must be logged in as a user with cluster-admin privileges.
Procedure

1. In the OpenShift Container Platform web console, click Operators → OperatorHub.

2. Use the Filter by keyword field to find the OADP Operator.

3. Select the OADP Operator and click Install.

4. Click Install to install the Operator in the openshift-adp project.

5. Click Operators → Installed Operators to verify the installation.

14.2.2. About backup and snapshot locations and their secrets

You specify backup and snapshot locations and their secrets in the DataProtectionApplication custom resource (CR).

Backup locations
You specify S3-compatible object storage, such as Multicloud Object Gateway, Noobaa, or Minio, as a backup location.

Velero backs up OpenShift Container Platform resources, Kubernetes objects, and internal images as an archive file on object storage.

Snapshot locations
If you use your cloud provider’s native snapshot API to back up virtual machine disks, you must specify the cloud provider as the snapshot location.

If you use Container Storage Interface (CSI) snapshots, you do not need to specify a snapshot location because you will create a VolumeSnapshotClass CR to register the CSI driver.

If you use Restic, you do not need to specify a snapshot location because Restic backs up the file system on object storage.

Secrets
If the backup and snapshot locations use the same credentials or if you do not require a snapshot location, you create a default Secret.

If the backup and snapshot locations use different credentials, you create two secret objects:

- Custom Secret for the backup location, which you specify in the DataProtectionApplication CR.

- Default Secret for the snapshot location, which is not referenced in the DataProtectionApplication CR.

IMPORTANT

The Data Protection Application requires a default Secret. Otherwise, the installation will fail.

If you do not want to specify backup or snapshot locations during the installation, you can create a default Secret with an empty credentials-velero file.

14.2.2.1. Creating a default Secret
You create a default Secret if your backup and snapshot locations use the same credentials or if you do not require a snapshot location.

The default name of the Secret is cloud-credentials, unless your backup storage provider has a default plug-in, such as aws, azure, or gcp. In that case, the default name is specified in the provider-specific OADP installation procedure.

NOTE

The DataProtectionApplication custom resource (CR) requires a default Secret. Otherwise, the installation will fail. If the name of the backup location Secret is not specified, the default name is used.

If you do not want to use the backup location credentials during the installation, you can create a Secret with the default name by using an empty credentials-velero file.

Prerequisites

- Your object storage and cloud storage, if any, must use the same credentials.
- You must configure object storage for Velero.
- You must create a credentials-velero file for the object storage in the appropriate format.

Procedure

- Create a Secret with the default name:

  $ oc create secret generic cloud-credentials -n openshift-adp --from-file cloud=credentials-velero

  The Secret is referenced in the spec.backupLocations.credential block of the DataProtectionApplication CR when you install the Data Protection Application.

14.2.2.2. Creating secrets for different credentials

If your backup and snapshot locations use different credentials, you must create two Secret objects:

- Backup location Secret with a custom name. The custom name is specified in the spec.backupLocations block of the DataProtectionApplication custom resource (CR).

- Snapshot location Secret with the default name, cloud-credentials. This Secret is not specified in the DataProtectionApplication CR.

Procedure

1. Create a credentials-velero file for the snapshot location in the appropriate format for your cloud provider.

2. Create a Secret for the snapshot location with the default name:

  $ oc create secret generic cloud-credentials -n openshift-adp --from-file cloud=credentials-velero
3. Create a `credentials-velero` file for the backup location in the appropriate format for your object storage.

4. Create a `Secret` for the backup location with a custom name:

   ```bash
   $ oc create secret generic <custom_secret> -n openshift-adp --from-file cloud=credentials-velero
   ```

5. Add the `Secret` with the custom name to the `DataProtectionApplication` CR, as in the following example:

   ```yaml
   apiVersion: oadp.openshift.io/v1alpha1
   kind: DataProtectionApplication
   metadata:
     name: <dpa_sample>
     namespace: openshift-adp
   spec:
     ... backupLocations:
     - velero:
         provider: <provider>
         default: true
         credential:
           key: cloud
           name: <custom_secret>  
         objectStorage:
           bucket: <bucket_name>
           prefix: <prefix>
   
   ^ Backup location Secret with custom name.

---

14.2.3. Configuring the Data Protection Application

You can configure the Data Protection Application by setting Velero resource allocations or enabling self-signed CA certificates.

### 14.2.3.1. Setting Velero CPU and memory resource allocations

You set the CPU and memory resource allocations for the `Velero` pod by editing the `DataProtectionApplication` custom resource (CR) manifest.

**Prerequisites**

- You must have the OpenShift API for Data Protection (OADP) Operator installed.

**Procedure**

- Edit the values in the `spec.configuration.velero.podConfig.ResourceAllocations` block of the `DataProtectionApplication` CR manifest, as in the following example:

  ```yaml
  apiVersion: oadp.openshift.io/v1alpha1
  kind: DataProtectionApplication
  metadata:
  ```
name: <dpa_sample>
spec:
  ...
configuration:
  velero:
    podConfig:
      resourceAllocations:
        limits:
          cpu: "1" ①
          memory: 512Mi ②
        requests:
          cpu: 500m ③
          memory: 256Mi ④

① Specify the value in millicpus or CPU units. Default value is 500m or 1 CPU unit.
② Default value is 512Mi.
③ Default value is 500m or 1 CPU unit.
④ Default value is 256Mi.

14.2.3.2. Enabling self-signed CA certificates

You must enable a self-signed CA certificate for object storage by editing the
DataProtectionApplication custom resource (CR) manifest to prevent a certificate signed by unknown authority error.

Prerequisites

- You must have the OpenShift API for Data Protection (OADP) Operator installed.

Procedure

- Edit the spec.backupLocations.velero.objectStorage.caCert parameter and spec.backupLocations.velero.config parameters of the DataProtectionApplication CR manifest:

apiVersion: oadp.openshift.io/v1alpha1
gold: DataProtectionApplication
metadata:
  name: <dpa_sample>
spec:
  ...
backupLocations:
  - name: default
    velero:
      provider: aws
default: true
      objectStorage:
        bucket: <bucket>
        prefix: <prefix>
      caCert: <base64_encoded_cert_string> ①
Specify the Base46-encoded CA certificate string.

Must be `false` to disable SSL/TLS security.

14.2.4. Installing the Data Protection Application

You install the Data Protection Application (DPA) by creating an instance of the `DataProtectionApplication` API.

**Prerequisites**

- You must install the OADP Operator.
- You must configure object storage as a backup location.
- If you use snapshots to back up PVs, your cloud provider must support either a native snapshot API or Container Storage Interface (CSI) snapshots.
- If the backup and snapshot locations use the same credentials, you must create a `Secret` with the default name, `cloud-credentials`.
- If the backup and snapshot locations use different credentials, you must create two `Secrets`:
  - `Secret` with a custom name for the backup location. You add this `Secret` to the `DataProtectionApplication` CR.
  - `Secret` with the default name, `cloud-credentials`, for the snapshot location. This `Secret` is not referenced in the `DataProtectionApplication` CR.

**NOTE**

If you do not want to specify backup or snapshot locations during the installation, you can create a default `Secret` with an empty `credentials-velero` file. If there is no default `Secret`, the installation will fail.

**Procedure**

1. Click **Operators → Installed Operators** and select the OADP Operator.
2. Under **Provided APIs**, click **Create instance** in the `DataProtectionApplication` box.
3. Click **YAML View** and update the parameters of the `DataProtectionApplication` manifest:

```yaml
apiVersion: oadp.openshift.io/v1alpha1
kind: DataProtectionApplication
metadata:
  name: <dpa_sample>
  namespace: openshift-adp
spec:
  configuration:
    config:
      insecureSkipTLSVerify: "false"
```


The **kubevirt** plug-in is mandatory for OpenShift Virtualization. Specify the plug-in for the backup provider, for example, **gcp**, if it exists. The **csi** plug-in is mandatory for backing up PVs with CSI snapshots. The **csi** plug-in uses the Velero CSI beta snapshot APIs. You do not need to configure a snapshot location. **The openshift** plug-in is mandatory. **The EnableCSI** feature flag is mandatory for CSI snapshots. Set to **false** if you want to disable the Restic installation. Restic deploys a daemon set, which means that each worker node has Restic pods running. You configure Restic for backups by adding **spec.defaultVolumesToRestic: true** to the Backup CR. Specify the backup provider. If you use a default plug-in for the backup provider, you must specify the correct default name for the Secret, for example, **cloud-credentials-gcp**. If you specify a custom name, the custom name is used for the backup location. If you do not specify a Secret name, the default name is used. Specify a bucket as the backup storage location. If the bucket is not a dedicated bucket for Velero backups, you must specify a prefix. Specify a prefix for Velero backups, for example, **velero**, if the bucket is used for multiple purposes.

4. Click **Create**.

5. Verify the installation by viewing the OADP resources:

```bash
$ oc get all -n openshift-adp
```

### Example output

<table>
<thead>
<tr>
<th>NAME</th>
<th>READY</th>
<th>STATUS</th>
<th>RESTARTS</th>
<th>AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pod/oadp-operator-controller-manager</td>
<td>2/2</td>
<td>Running 0</td>
<td>0</td>
<td>2m8s</td>
</tr>
<tr>
<td>pod/oadp-velero-sample-1-aws-registry</td>
<td>1/1</td>
<td>Running 0</td>
<td>0</td>
<td>95s</td>
</tr>
<tr>
<td>pod/restic-9cq4q</td>
<td>1/1</td>
<td>Running 0</td>
<td>0</td>
<td>94s</td>
</tr>
<tr>
<td>pod/restic-m4lts</td>
<td>1/1</td>
<td>Running 0</td>
<td>0</td>
<td>94s</td>
</tr>
<tr>
<td>pod/restic-pv4kr</td>
<td>1/1</td>
<td>Running 0</td>
<td>0</td>
<td>95s</td>
</tr>
<tr>
<td>pod/velero-588db7f655-n842v</td>
<td>1/1</td>
<td>Running 0</td>
<td>0</td>
<td>95s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>CLUSTER-IP</th>
<th>EXTERNAL-IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORT(S) AGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>service/oadp-operator-controller-manager-metrics-service</td>
<td>ClusterIP</td>
<td>172.30.70.140</td>
<td></td>
</tr>
</tbody>
</table>
14.2.4.1. Enabling CSI in the DataProtectionApplication CR

You enable the Container Storage Interface (CSI) in the DataProtectionApplication custom resource (CR) in order to back up persistent volumes with CSI snapshots.

Prerequisites

- The cloud provider must support CSI snapshots.

Procedure

- Edit the DataProtectionApplication CR, as in the following example:

```yaml
apiVersion: oadp.openshift.io/v1alpha1
kind: DataProtectionApplication
...
spec:
  configuration:
    velero:
      defaultPlugins:
        - openshift
        - csi
      featureFlags:
        - EnableCSI
```

1. Add the csi default plug-in.
2. Add the EnableCSI feature flag.

14.2.5. Uninstalling OADP

You uninstall the OpenShift API for Data Protection (OADP) by deleting the OADP Operator. See Deleting Operators from a cluster for details.

14.3. BACKING UP VIRTUAL MACHINES
You back up virtual machines (VMs) by creating an OpenShift API for Data Protection (OADP) Backup custom resource (CR).

The **Backup** CR performs the following actions:

- Backs up OpenShift Virtualization resources by creating an archive file on S3-compatible object storage, such as MultiCloud Object Gateway, Noobaa, or Minio.

- Backs up VM disks by using one of the following options:
  - **Container Storage Interface (CSI) snapshots** on CSI-enabled cloud storage, such as Ceph RBD or Ceph FS.
  - **Restic file system backups** on object storage.

**NOTE**

OADP provides backup hooks to freeze the VM file system before the backup operation and unfreeze it when the backup is complete.

The **kubervirt-controller** creates the **virt-launcher** pods with annotations that enable Velero to run the **virt-freezer** binary before and after the backup operation.

The **freeze** and **unfreeze** APIs are subresources of the VM snapshot API. See **About virtual machine snapshots** for details.

You can add hooks to the **Backup** CR to run commands on specific VMs before or after the backup operation.

You schedule a backup by creating a **Schedule CR** instead of a **Backup** CR.

### 14.3.1. Creating a Backup CR

You back up Kubernetes images, internal images, and persistent volumes (PVs) by creating a **Backup** custom resource (CR).

**Prerequisites**

- You must install the OpenShift API for Data Protection (OADP) Operator.

- The **DataProtectionApplication** CR must be in a **Ready** state.

- Backup location prerequisites:
  - You must have S3 object storage configured for Velero.
  - You must have a backup location configured in the **DataProtectionApplication** CR.

- Snapshot location prerequisites:
  - Your cloud provider must have a native snapshot API or support Container Storage Interface (CSI) snapshots.
  - For CSI snapshots, you must create a **VolumeSnapshotClass** CR to register the CSI driver.
  - You must have a volume location configured in the **DataProtectionApplication** CR.
Procedure

1. Retrieve the `backupStorageLocations` CRs:

   ```
   $ oc get backupStorageLocations
   ```

   **Example output**

<table>
<thead>
<tr>
<th>NAME</th>
<th>PHASE</th>
<th>LAST VALIDATED</th>
<th>AGE</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>velero-sample-1</td>
<td>Available</td>
<td>11s</td>
<td>31m</td>
<td></td>
</tr>
</tbody>
</table>

2. Create a `Backup` CR, as in the following example:

   ```
   apiVersion: velero.io/v1
   kind: Backup
   metadata:
     name: <backup>
     labels:
       velero.io/storage-location: default
       namespace: openshift-adp
   spec:
     hooks: {}
     includedNamespaces:
       - <namespace>
     includeClusterResources: true
     storageLocation: <velero-sample-1>
     ttl: 720h0m0s
   ```

   1. Specify an array of namespaces to back up.
   2. Specify the name of the `backupStorageLocations` CR.

3. Verify that the status of the `Backup` CR is `Completed`:

   ```
   $ oc get backup -n openshift-adp <backup> -o jsonpath='{.status.phase}'
   ```

14.3.1.1. Backing up persistent volumes with CSI snapshots

You back up persistent volumes with Container Storage Interface (CSI) snapshots by editing the `VolumeSnapshotClass` custom resource (CR) of the cloud storage before you create the `Backup` CR.

**Prerequisites**

- The cloud provider must support CSI snapshots.
- You must enable CSI in the `DataProtectionApplication` CR.

**Procedure**

- Add the `metadata.labels.velero.io/csi-volumesnapshot-class: "true"` key-value pair to the `VolumeSnapshotClass` CR:

   ```
   apiVersion: snapshot.storage.k8s.io/v1
   ```
14.3.1.2. Backing up applications with Restic

You back up Kubernetes resources, internal images, and persistent volumes with Restic by editing the `Backup` custom resource (CR).

You do not need to specify a snapshot location in the `DataProtectionApplication` CR.

**Prerequisites**

- You must install the OpenShift API for Data Protection (OADP) Operator.
- You must not disable the default Restic installation by setting `spec.configuration.restic.enable` to `false` in the `DataProtectionApplication` CR.
- The `DataProtectionApplication` CR must be in a `Ready` state.

**Procedure**

- Edit the `Backup` CR, as in the following example:

```yaml
kind: VolumeSnapshotClass
metadata:
  name: '<volume_snapshot_class_name>'
labels:
  velero.io/csi-volumesnapshot-class: "true"
driver: '<csi_driver>'
deletionPolicy: Retain
```

You can now create a `Backup` CR.

14.3.1.3. Creating backup hooks

You create backup hooks to run commands in a container in a pod by editing the `Backup` custom resource (CR).

Pre hooks run before the pod is backed up. Post hooks run after the backup.

**Procedure**

- Add a hook to the `spec.hooks` block of the `Backup` CR, as in the following example:

```yaml
  kind: VolumeSnapshotClass
  metadata:
    name: '<volume_snapshot_class_name>'
  labels:
    velero.io/csi-volumesnapshot-class: "true"
  driver: '<csi_driver>'
  deletionPolicy: Retain
```

Add `defaultVolumesToRestic: true` to the `spec` block.
apiVersion: velero.io/v1
kind: Backup
metadata:
  name: <backup>
  namespace: openshift-adp
spec:
  hooks:
    resources:
      - name: <hook_name>
        includedNamespaces:
          - <namespace>
        excludedNamespaces:
          - <namespace>
        includedResources:
          - pods
        excludedResources: []
    labelSelector:
      matchLabels:
        app: velero
        component: server
    pre:
      - exec:
          container: <container>
          command:
            - /bin/uname
            - -a
          onError: Fail
          timeout: 30s
    post:

1. Array of namespaces to which the hook applies. If this value is not specified, the hook applies to all namespaces.

2. Currently, pods are the only supported resource.

3. Optional: This hook only applies to objects matching the label selector.

4. Array of hooks to run before the backup.

5. Optional: If the container is not specified, the command runs in the first container in the pod.

6. Array of commands that the hook runs.

7. Allowed values for error handling are Fail and Continue. The default is Fail.

8. Optional: How long to wait for the commands to run. The default is 30s.

9. This block defines an array of hooks to run after the backup, with the same parameters as the pre-backup hooks.

14.3.2. Scheduling backups
You schedule backups by creating a Schedule custom resource (CR) instead of a Backup CR.

**Prerequisites**

- You must install the OpenShift API for Data Protection (OADP) Operator.
- The DataProtectionApplication CR must be in a Ready state.

**Procedure**

1. Retrieve the backupStorageLocations CRs:

   ```
   $ oc get backupStorageLocations
   ```

   **Example output**

   ```
   NAME              PHASE       LAST VALIDATED   AGE   DEFAULT
   velero-sample-1   Available   11s              31m
   ```

2. Create a Schedule CR, as in the following example:

   ```
   $ cat << EOF | oc apply -f -
   apiVersion: velero.io/v1
   kind: Schedule
   metadata:
     name: <schedule>
     namespace: openshift-adp
   spec:
     schedule: 0 7 * * *
     template:
       hooks: {}
       includedNamespaces:
         - <namespace>
       storageLocation: <velero-sample-1>
       includeClusterResources: true
       defaultVolumesToRestic: true
       ttl: 720h0m0s
   EOF
   ```

   **Notes:**

   1. Cron expression to schedule the backup, for example, 0 7 * * * to perform a backup every day at 7:00.
   2. Array of namespaces to back up.
   3. Name of the backupStorageLocations CR.
   4. Optional: Add the defaultVolumesToRestic: true key-value pair if you are backing up volumes with Restic.

3. Verify that the status of the Schedule CR is Completed after the scheduled backup runs:

   ```
   $ oc get schedule -n openshift-adp <schedule> -o jsonpath='{.status.phase}'
   ```
14.3.3. Additional resources

- Overview of CSI volume snapshots

14.4. RESTORING VIRTUAL MACHINES

You restore an OpenShift API for Data Protection (OADP) **Backup** custom resource (CR) by creating a **Restore** CR.

You can add **hooks** to the **Restore** CR to run commands in init containers, before the application container starts, or in the application container itself.

14.4.1. Creating a Restore CR

You restore a **Backup** custom resource (CR) by creating a **Restore** CR.

**Prerequisites**

- You must install the OpenShift API for Data Protection (OADP) Operator.
- The **DataProtectionApplication** CR must be in a **Ready** state.
- You must have a Velero **Backup** CR.

**Procedure**

1. Create a **Restore** CR, as in the following example:

   ```yaml
   apiVersion: velero.io/v1
   kind: Restore
   metadata:
     name: <restore>  
     namespace: openshift-adp
   spec:
     backupName: <backup>  
     excludedResources:
       - nodes
       - events
       - events.events.k8s.io
       - backups.velero.io
       - restores.velero.io
       - resticrepositories.velero.io
     restorePVs: true
   
   Name of the **Backup** CR.
   
   1
   
2. Verify that the status of the **Restore** CR is **Completed**:

   ```bash
   $ oc get restore -n openshift-adp <restore> -o jsonpath='{.status.phase}'
   
   Name of the **Backup** CR.
   
   1
   
3. Verify that the backup resources have been restored:

   ```bash
   $ oc get all -n <namespace>
   
   Name of the namespace.
   
   1
   ```
Namespace that you backed up.

14.4.1.1. Creating restore hooks

You create restore hooks to run commands in a container in a pod while restoring your application by editing the `Restore` custom resource (CR).

You can create two types of restore hooks:

- An **init** hook adds an init container to a pod to perform setup tasks before the application container starts.
  - If you restore a Restic backup, the **restic-wait** init container is added before the restore hook init container.

- An **exec** hook runs commands or scripts in a container of a restored pod.

**Procedure**

- Add a hook to the `spec.hooks` block of the `Restore` CR, as in the following example:

```yaml
apiVersion: velero.io/v1
kind: Restore
metadata:
  name: <restore>
  namespace: openshift-adp
spec:
  hooks:
    resources:
      - name: <hook_name>  
        includedNamespaces:
          - <namespace>
        excludedNamespaces:
          - <namespace>
        includedResources:
          - pods
        excludedResources: []
      labelSelector: {}
      matchLabels:
        app: velero
        component: server
    postHooks:
      - init:
        initContainers:
          - name: restore-hook-init
            image: alpine:latest
            volumeMounts:
              - mountPath: /restores/pvc1-vm
                name: pvc1-vm
            command:
              - /bin/ash
              -c
      - exec:
        container: <container>
        command:
```
Optional: Array of namespaces to which the hook applies. If this value is not specified, the hook applies to all namespaces.

Currently, pods are the only supported resource.

Optional: This hook only applies to objects matching the label selector.

Optional: If the container is not specified, the command runs in the first container in the pod.

Array of commands that the hook runs.

Optional: If the `waitTimeout` is not specified, the restore waits indefinitely. You can specify how long to wait for a container to start and for preceding hooks in the container to complete. The wait timeout starts when the container is restored and might require time for the container to pull the image and mount the volumes.

Optional: How long to wait for the commands to run. The default is `30s`.

Allowed values for error handling are `Fail` and `Continue`:

- **Continue**: Only command failures are logged.

- **Fail**: No more restore hooks run in any container in any pod. The status of the Restore CR will be `PartiallyFailed`. 