OpenShift Container Platform 4.18

Storage

Configuring and managing storage in OpenShift Container Platform

Last Updated: 2025-06-10

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Abstract

This document provides instructions for configuring persistent volumes from various storage back ends and managing dynamic allocation from Pods.

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CHAPTER 1. OPENSHIFT CONTAINER PLATFORM STORAGE OVERVIEW

OpenShift Container Platform supports multiple types of storage, both for on-premise and cloud providers. You can manage container storage for persistent and non-persistent data in an OpenShift Container Platform cluster.

1.1. GLOSSARY OF COMMON TERMS FOR OPENSHIFT CONTAINER PLATFORM STORAGE

This glossary defines common terms that are used in the storage content.

Access modes

Volume access modes describe volume capabilities. You can use access modes to match persistent volume claim (PVC) and persistent volume (PV). The following are the examples of access modes:

- ReadWriteOnce (RWO)
- ReadOnlyMany (ROX)
- ReadWriteMany (RWX)
- ReadWriteOncePod (RWOP)

Cinder

The Block Storage service for Red Hat OpenStack Platform (RHOSP) which manages the administration, security, and scheduling of all volumes.

Config map

A config map provides a way to inject configuration data into pods. You can reference the data stored in a config map in a volume of type **ConfigMap**. Applications running in a pod can use this data.

Container Storage Interface (CSI)

An API specification for the management of container storage across different container orchestration (CO) systems.

Dynamic Provisioning

The framework allows you to create storage volumes on-demand, eliminating the need for cluster administrators to pre-provision persistent storage.

Ephemeral storage

Pods and containers can require temporary or transient local storage for their operation. The lifetime of this ephemeral storage does not extend beyond the life of the individual pod, and this ephemeral storage cannot be shared across pods.

Fiber channel

A networking technology that is used to transfer data among data centers, computer servers, switches and storage.

FlexVolume

FlexVolume is an out-of-tree plugin interface that uses an exec-based model to interface with storage drivers. You must install the FlexVolume driver binaries in a pre-defined volume plugin path on each node and in some cases the control plane nodes.

fsGroup

The fsGroup defines a file system group ID of a pod.

iSCSI

Internet Small Computer Systems Interface (iSCSI) is an Internet Protocol-based storage networking standard for linking data storage facilities. An iSCSI volume allows an existing iSCSI (SCSI over IP) volume to be mounted into your Pod.

hostPath

A hostPath volume in an OpenShift Container Platform cluster mounts a file or directory from the host node's filesystem into your pod.

KMS key

The Key Management Service (KMS) helps you achieve the required level of encryption of your data across different services. you can use the KMS key to encrypt, decrypt, and re-encrypt data.

Local volumes

A local volume represents a mounted local storage device such as a disk, partition or directory.

NFS

A Network File System (NFS) that allows remote hosts to mount file systems over a network and interact with those file systems as though they are mounted locally. This enables system administrators to consolidate resources onto centralized servers on the network.

OpenShift Data Foundation

A provider of agnostic persistent storage for OpenShift Container Platform supporting file, block, and object storage, either in-house or in hybrid clouds

Persistent storage

Pods and containers can require permanent storage for their operation. OpenShift Container Platform uses the Kubernetes persistent volume (PV) framework to allow cluster administrators to provision persistent storage for a cluster. Developers can use PVC to request PV resources without having specific knowledge of the underlying storage infrastructure.

Persistent volumes (PV)

OpenShift Container Platform uses the Kubernetes persistent volume (PV) framework to allow cluster administrators to provision persistent storage for a cluster. Developers can use PVC to request PV resources without having specific knowledge of the underlying storage infrastructure.

Persistent volume claims (PVCs)

You can use a PVC to mount a PersistentVolume into a Pod. You can access the storage without knowing the details of the cloud environment.

Pod

One or more containers with shared resources, such as volume and IP addresses, running in your OpenShift Container Platform cluster. A pod is the smallest compute unit defined, deployed, and managed.

Reclaim policy

A policy that tells the cluster what to do with the volume after it is released. A volume's reclaim policy can be **Retain**, **Recycle**, or **Delete**.

Role-based access control (RBAC)

Role-based access control (RBAC) is a method of regulating access to computer or network resources based on the roles of individual users within your organization.

Stateless applications

A stateless application is an application program that does not save client data generated in one session for use in the next session with that client.

Stateful applications

A stateful application is an application program that saves data to persistent disk storage. A server, client, and applications can use a persistent disk storage. You can use the **Statefulset** object in OpenShift Container Platform to manage the deployment and scaling of a set of Pods, and provides guarantee about the ordering and uniqueness of these Pods.

Static provisioning

A cluster administrator creates a number of PVs. PVs contain the details of storage. PVs exist in the Kubernetes API and are available for consumption.

Storage

OpenShift Container Platform supports many types of storage, both for on-premise and cloud providers. You can manage container storage for persistent and non-persistent data in an OpenShift Container Platform cluster.

Storage class

A storage class provides a way for administrators to describe the classes of storage they offer. Different classes might map to quality of service levels, backup policies, arbitrary policies determined by the cluster administrators.

VMware vSphere's Virtual Machine Disk (VMDK) volumes

Virtual Machine Disk (VMDK) is a file format that describes containers for virtual hard disk drives that is used in virtual machines.

1.2. STORAGE TYPES

OpenShift Container Platform storage is broadly classified into two categories, namely ephemeral storage and persistent storage.

1.2.1. Ephemeral storage

Pods and containers are ephemeral or transient in nature and designed for stateless applications. Ephemeral storage allows administrators and developers to better manage the local storage for some of their operations. For more information about ephemeral storage overview, types, and management, see Understanding ephemeral storage .

1.2.2. Persistent storage

Stateful applications deployed in containers require persistent storage. OpenShift Container Platform uses a pre-provisioned storage framework called persistent volumes (PV) to allow cluster administrators to provision persistent storage. The data inside these volumes can exist beyond the lifecycle of an individual pod. Developers can use persistent volume claims (PVCs) to request storage requirements. For more information about persistent storage overview, configuration, and lifecycle, see Understanding persistent storage.

1.3. CONTAINER STORAGE INTERFACE (CSI)

CSI is an API specification for the management of container storage across different container orchestration (CO) systems. You can manage the storage volumes within the container native environments, without having specific knowledge of the underlying storage infrastructure. With the CSI, storage works uniformly across different container orchestration systems, regardless of the storage vendors you are using. For more information about CSI, see Using Container Storage Interface (CSI) .

1.4. DYNAMIC PROVISIONING

Dynamic Provisioning allows you to create storage volumes on-demand, eliminating the need for cluster administrators to pre-provision storage. For more information about dynamic provisioning, see Dynamic provisioning.

CHAPTER 2. UNDERSTANDING EPHEMERAL STORAGE

2.1. OVERVIEW

In addition to persistent storage, pods and containers can require ephemeral or transient local storage for their operation. The lifetime of this ephemeral storage does not extend beyond the life of the individual pod, and this ephemeral storage cannot be shared across pods.

Pods use ephemeral local storage for scratch space, caching, and logs. Issues related to the lack of local storage accounting and isolation include the following:

- Pods cannot detect how much local storage is available to them.
- Pods cannot request guaranteed local storage.
- Local storage is a best-effort resource.
- Pods can be evicted due to other pods filling the local storage, after which new pods are not admitted until sufficient storage is reclaimed.

Unlike persistent volumes, ephemeral storage is unstructured and the space is shared between all pods running on a node, in addition to other uses by the system, the container runtime, and OpenShift Container Platform. The ephemeral storage framework allows pods to specify their transient local storage needs. It also allows OpenShift Container Platform to schedule pods where appropriate, and to protect the node against excessive use of local storage.

While the ephemeral storage framework allows administrators and developers to better manage local storage, I/O throughput and latency are not directly effected.

2.2. TYPES OF EPHEMERAL STORAGE

Ephemeral local storage is always made available in the primary partition. There are two basic ways of creating the primary partition: root and runtime.

Root

This partition holds the kubelet root directory, **/var/lib/kubelet/** by default, and **/var/log/** directory. This partition can be shared between user pods, the OS, and Kubernetes system daemons. This partition can be consumed by pods through **EmptyDir** volumes, container logs, image layers, and container-writable layers. Kubelet manages shared access and isolation of this partition. This partition is ephemeral, and applications cannot expect any performance SLAs, such as disk IOPS, from this partition.

Runtime

This is an optional partition that runtimes can use for overlay file systems. OpenShift Container Platform attempts to identify and provide shared access along with isolation to this partition. Container image layers and writable layers are stored here. If the runtime partition exists, the **root** partition does not hold any image layer or other writable storage.

2.3. EPHEMERAL STORAGE MANAGEMENT

Cluster administrators can manage ephemeral storage within a project by setting quotas that define the limit ranges and number of requests for ephemeral storage across all pods in a non-terminal state. Developers can also set requests and limits on this compute resource at the pod and container level.

You can manage local ephemeral storage by specifying requests and limits. Each container in a pod can specify the following:

- **spec.containers[].resources.limits.ephemeral-storage**
- **spec.containers[].resources.requests.ephemeral-storage**

2.3.1. Ephemeral storage limits and requests units

Limits and requests for ephemeral storage are measured in byte quantities. You can express storage as a plain integer or as a fixed-point number using one of these suffixes: E, P, T, G, M, k. You can also use the power-of-two equivalents: Ei, Pi, Ti, Gi, Mi, Ki.

For example, the following quantities all represent approximately the same value: 128974848, 129e6, 129M, and 123Mi.

IMPORTANT

The suffixes for each byte quantity are case-sensitive. Be sure to use the correct case. Use the case-sensitive "M", such as used in "400M" to set the request at 400 megabytes. Use the case-sensitive "400Mi" to request 400 mebibytes. If you specify "400m" of ephemeral storage, the storage requests is only 0.4 bytes.

2.3.2. Ephemeral storage requests and limits example

The following example configuration file shows a pod with two containers:

- Each container requests 2GiB of local ephemeral storage.
- Each container has a limit of 4GiB of local ephemeral storage.
- At the pod level, kubelet works out an overall pod storage limit by adding up the limits of all the containers in that pod.
  - In this case, the total storage usage at the pod level is the sum of the disk usage from all containers plus the pod's **emptyDir** volumes.
  - Therefore, the pod has a request of 4GiB of local ephemeral storage, and a limit of 8GiB of local ephemeral storage.

Example ephemeral storage configuration with quotas and limits

```
apiVersion: v1
kind: Pod
metadata:
  name: frontend
spec:
  containers:
  - name: app
    image: images.my-company.example/app:v4
    resources:
      requests:
        ephemeral-storage: "2Gi" (1)
      limits:
        ephemeral-storage: "4Gi" (2)
```

```
    volumeMounts:
    - name: ephemeral
      mountPath: "/tmp"
  - name: log-aggregator
    image: images.my-company.example/log-aggregator:v6
    resources:
      requests:
        ephemeral-storage: "2Gi"
      limits:
        ephemeral-storage: "4Gi"
    volumeMounts:
    - name: ephemeral
      mountPath: "/tmp"
  volumes:
    - name: ephemeral
      emptyDir: {}
```

1. Container request for local ephemeral storage.
2. Container limit for local ephemeral storage.

2.3.3. Ephemeral storage configuration effects pod scheduling and eviction

The settings in the pod spec affect both how the scheduler makes a decision about scheduling pods and when kubelet evicts pods.

- First, the scheduler ensures that the sum of the resource requests of the scheduled containers is less than the capacity of the node. In this case, the pod can be assigned to a node only if the node's available ephemeral storage (allocatable resource) is more than 4GiB.
- Second, at the container level, because the first container sets a resource limit, kubelet eviction manager measures the disk usage of this container and evicts the pod if the storage usage of the container exceeds its limit (4GiB). The kubelet eviction manager also marks the pod for eviction if the total usage exceeds the overall pod storage limit (8GiB).

For information about defining quotas for projects, see Quota setting per project.

2.4. MONITORING EPHEMERAL STORAGE

You can use **/bin/df** as a tool to monitor ephemeral storage usage on the volume where ephemeral container data is located, which is **/var/lib/kubelet** and **/var/lib/containers**. The available space for only **/var/lib/kubelet** is shown when you use the **df** command if **/var/lib/containers** is placed on a separate disk by the cluster administrator.

To show the human-readable values of used and available space in **/var/lib**, enter the following command:

```
$ df -h /var/lib
```

The output shows the ephemeral storage usage in **/var/lib**:

Example output

```
Filesystem  Size  Used Avail Use% Mounted on
/dev/disk/by-partuuid/4cd1448a-01    69G   32G   34G  49% /
```

CHAPTER 3. UNDERSTANDING PERSISTENT STORAGE

3.1. PERSISTENT STORAGE OVERVIEW

Managing storage is a distinct problem from managing compute resources. OpenShift Container Platform uses the Kubernetes persistent volume (PV) framework to allow cluster administrators to provision persistent storage for a cluster. Developers can use persistent volume claims (PVCs) to request PV resources without having specific knowledge of the underlying storage infrastructure.

PVCs are specific to a project, and are created and used by developers as a means to use a PV. PV resources on their own are not scoped to any single project; they can be shared across the entire OpenShift Container Platform cluster and claimed from any project. After a PV is bound to a PVC, that PV can not then be bound to additional PVCs. This has the effect of scoping a bound PV to a single namespace, that of the binding project.

PVs are defined by a **PersistentVolume** API object, which represents a piece of existing storage in the cluster that was either statically provisioned by the cluster administrator or dynamically provisioned using a **StorageClass** object. It is a resource in the cluster just like a node is a cluster resource.

PVs are volume plugins like **Volumes** but have a lifecycle that is independent of any individual pod that uses the PV. PV objects capture the details of the implementation of the storage, be that NFS, iSCSI, or a cloud-provider-specific storage system.

IMPORTANT

High availability of storage in the infrastructure is left to the underlying storage provider.

PVCs are defined by a **PersistentVolumeClaim** API object, which represents a request for storage by a developer. It is similar to a pod in that pods consume node resources and PVCs consume PV resources. For example, pods can request specific levels of resources, such as CPU and memory, while PVCs can request specific storage capacity and access modes. For example, they can be mounted once read-write or many times read-only.

3.2. LIFECYCLE OF A VOLUME AND CLAIM

PVs are resources in the cluster. PVCs are requests for those resources and also act as claim checks to the resource. The interaction between PVs and PVCs have the following lifecycle.

3.2.1. Provision storage

In response to requests from a developer defined in a PVC, a cluster administrator configures one or more dynamic provisioners that provision storage and a matching PV.

Alternatively, a cluster administrator can create a number of PVs in advance that carry the details of the real storage that is available for use. PVs exist in the API and are available for use.

3.2.2. Bind claims

When you create a PVC, you request a specific amount of storage, specify the required access mode, and create a storage class to describe and classify the storage. The control loop in the master watches for new PVCs and binds the new PVC to an appropriate PV. If an appropriate PV does not exist, a provisioner for the storage class creates one.

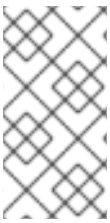
The size of all PVs might exceed your PVC size. This is especially true with manually provisioned PVs. To minimize the excess, OpenShift Container Platform binds to the smallest PV that matches all other criteria.

Claims remain unbound indefinitely if a matching volume does not exist or can not be created with any available provisioner servicing a storage class. Claims are bound as matching volumes become available. For example, a cluster with many manually provisioned 50Gi volumes would not match a PVC requesting 100Gi. The PVC can be bound when a 100Gi PV is added to the cluster.

3.2.3. Use pods and claimed PVs

Pods use claims as volumes. The cluster inspects the claim to find the bound volume and mounts that volume for a pod. For those volumes that support multiple access modes, you must specify which mode applies when you use the claim as a volume in a pod.

Once you have a claim and that claim is bound, the bound PV belongs to you for as long as you need it. You can schedule pods and access claimed PVs by including **persistentVolumeClaim** in the pod's volumes block.



NOTE

If you attach persistent volumes that have high file counts to pods, those pods can fail or can take a long time to start. For more information, see When using Persistent Volumes with high file counts in OpenShift, why do pods fail to start or take an excessive amount of time to achieve "Ready" state?.

3.2.4. Storage Object in Use Protection

The Storage Object in Use Protection feature ensures that PVCs in active use by a pod and PVs that are bound to PVCs are not removed from the system, as this can result in data loss.

Storage Object in Use Protection is enabled by default.

NOTE

A PVC is in active use by a pod when a **Pod** object exists that uses the PVC.

If a user deletes a PVC that is in active use by a pod, the PVC is not removed immediately. PVC removal is postponed until the PVC is no longer actively used by any pods. Also, if a cluster admin deletes a PV that is bound to a PVC, the PV is not removed immediately. PV removal is postponed until the PV is no longer bound to a PVC.

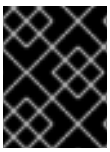
3.2.5. Release a persistent volume

When you are finished with a volume, you can delete the PVC object from the API, which allows reclamation of the resource. The volume is considered released when the claim is deleted, but it is not yet available for another claim. The previous claimant's data remains on the volume and must be handled according to policy.

3.2.6. Reclaim policy for persistent volumes

The reclaim policy of a persistent volume tells the cluster what to do with the volume after it is released. A volume's reclaim policy can be **Retain**, **Recycle**, or **Delete**.

- **Retain** reclaim policy allows manual reclamation of the resource for those volume plugins that support it.
- **Recycle** reclaim policy recycles the volume back into the pool of unbound persistent volumes once it is released from its claim.



IMPORTANT

The **Recycle** reclaim policy is deprecated in OpenShift Container Platform 4. Dynamic provisioning is recommended for equivalent and better functionality.

- **Delete** reclaim policy deletes both the **PersistentVolume** object from OpenShift Container Platform and the associated storage asset in external infrastructure, such as Amazon Elastic Block Store (Amazon EBS) or VMware vSphere.

NOTE

Dynamically provisioned volumes are always deleted.

3.2.7. Reclaiming a persistent volume manually

When a persistent volume claim (PVC) is deleted, the persistent volume (PV) still exists and is considered "released". However, the PV is not yet available for another claim because the data of the previous claimant remains on the volume.

Procedure

To manually reclaim the PV as a cluster administrator:

1. Delete the PV.

```
$ oc delete pv <pv-name>
```

   The associated storage asset in the external infrastructure, such as an AWS EBS, GCE PD, Azure Disk, or Cinder volume, still exists after the PV is deleted.

2. Clean up the data on the associated storage asset.
3. Delete the associated storage asset. Alternately, to reuse the same storage asset, create a new PV with the storage asset definition.

The reclaimed PV is now available for use by another PVC.

3.2.8. Changing the reclaim policy of a persistent volume

To change the reclaim policy of a persistent volume:

1. List the persistent volumes in your cluster:

```
$ oc get pv
```

   Example output

```
NAME                        CAPACITY   ACCESSMODES   RECLAIMPOLICY   STATUS
```

```
CLAIM           STORAGECLASS     REASON    AGE
 pvc-b6efd8da-b7b5-11e6-9d58-0ed433a7dd94   4Gi        RWO           Delete          Bound
default/claim1    manual                    10s
 pvc-b95650f8-b7b5-11e6-9d58-0ed433a7dd94   4Gi        RWO           Delete          Bound
default/claim2    manual                    6s
 pvc-bb3ca71d-b7b5-11e6-9d58-0ed433a7dd94   4Gi        RWO           Delete          Bound
default/claim3    manual                    3s
```

2. Choose one of your persistent volumes and change its reclaim policy:

```
$ oc patch pv <your-pv-name> -p '{"spec":{"persistentVolumeReclaimPolicy":"Retain"}}'
```

3. Verify that your chosen persistent volume has the right policy:

```
$ oc get pv
```

Example output

```
NAME                                       CAPACITY   ACCESSMODES   RECLAIMPOLICY   STATUS
CLAIM           STORAGECLASS     REASON    AGE
 pvc-b6efd8da-b7b5-11e6-9d58-0ed433a7dd94   4Gi        RWO           Delete          Bound
default/claim1    manual                    10s
 pvc-b95650f8-b7b5-11e6-9d58-0ed433a7dd94   4Gi        RWO           Delete          Bound
default/claim2    manual                    6s
 pvc-bb3ca71d-b7b5-11e6-9d58-0ed433a7dd94   4Gi        RWO           Retain          Bound
default/claim3    manual                    3s
```

In the preceding output, the volume bound to claim **default/claim3** now has a **Retain** reclaim policy. The volume will not be automatically deleted when a user deletes claim **default/claim3**.

3.3. PERSISTENT VOLUMES

Each PV contains a **spec** and **status**, which is the specification and status of the volume, for example:

PersistentVolume object definition example

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: pv0001 (1)
spec:
  capacity:
    storage: 5Gi (2)
  accessModes:
    - ReadWriteOnce (3)
  persistentVolumeReclaimPolicy: Retain (4)
  ...
status:
  ...
```

(1) Name of the persistent volume.

2 The amount of storage available to the volume.

3 The access mode, defining the read-write and mount permissions.

4 The reclaim policy, indicating how the resource should be handled once it is released.

You can view the name of a PVC that is bound to a PV by running the following command:

```
$ oc get pv <pv-name> -o jsonpath='{.spec.claimRef.name}'
```

3.3.1. Types of PVs

OpenShift Container Platform supports the following persistent volume plugins:

- AWS Elastic Block Store (EBS)
- AWS Elastic File Store (EFS)
- Azure Disk
- Azure File
- Cinder
- Fibre Channel
- GCP Persistent Disk
- GCP Filestore
- IBM Power Virtual Server Block
- IBM Cloud® VPC Block
- HostPath
- iSCSI
- Local volume
- NFS
- OpenStack Manila
- Red Hat OpenShift Data Foundation
- CIFS/SMB
- VMware vSphere

3.3.2. Capacity

Generally, a persistent volume (PV) has a specific storage capacity. This is set by using the **capacity** attribute of the PV.

Currently, storage capacity is the only resource that can be set or requested. Future attributes may include IOPS, throughput, and so on.

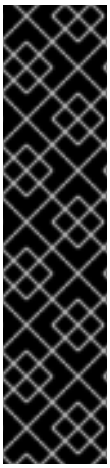
3.3.3. Access modes

A persistent volume can be mounted on a host in any way supported by the resource provider. Providers have different capabilities and each PV's access modes are set to the specific modes supported by that particular volume. For example, NFS can support multiple read-write clients, but a specific NFS PV might be exported on the server as read-only. Each PV gets its own set of access modes describing that specific PV's capabilities.

Claims are matched to volumes with similar access modes. The only two matching criteria are access modes and size. A claim's access modes represent a request. Therefore, you might be granted more, but never less. For example, if a claim requests RWO, but the only volume available is an NFS PV (RWO+ROX+RWX), the claim would then match NFS because it supports RWO.

Direct matches are always attempted first. The volume's modes must match or contain more modes than you requested. The size must be greater than or equal to what is expected. If two types of volumes, such as NFS and iSCSI, have the same set of access modes, either of them can match a claim with those modes. There is no ordering between types of volumes and no way to choose one type over another.

All volumes with the same modes are grouped, and then sorted by size, smallest to largest. The binder gets the group with matching modes and iterates over each, in size order, until one size matches.



IMPORTANT

Volume access modes describe volume capabilities. They are not enforced constraints. The storage provider is responsible for runtime errors resulting from invalid use of the resource. Errors in the provider show up at runtime as mount errors.

For example, NFS offers **ReadWriteOnce** access mode. If you want to use the volume's ROX capability, mark the claims as **ReadOnlyMany**.

iSCSI and Fibre Channel volumes do not currently have any fencing mechanisms. You must ensure the volumes are only used by one node at a time. In certain situations, such as draining a node, the volumes can be used simultaneously by two nodes. Before draining the node, delete the pods that use the volumes.

The following table lists the access modes:

Table 3.1. Access modes

Access Mode	CLI abbreviation	Description
ReadWriteOnce	**RWO**	The volume can be mounted as read-write by a single node.
ReadWriteOncePod [1]	**RWOP**	The volume can be mounted as read-write by a single pod on a single node.
ReadOnlyMany	**ROX**	The volume can be mounted as read-only by many nodes.
ReadWriteMany	**RWX**	The volume can be mounted as read-write by many nodes.

1. RWOP uses the SELinux mount feature. This feature is driver dependent, and enabled by default in ODF, AWS EBS, Azure Disk, GCP PD, IBM Cloud Block Storage volume, Cinder, and vSphere. For third-party drivers, please contact your storage vendor.

Table 3.2. Supported access modes for persistent volumes

Volume plugin	ReadWriteOnce [1]	ReadWriteOncePod	ReadOnlyMany	ReadWriteMany
AWS EBS [2]	▮	▮		
AWS EFS	▮	▮	▮	▮
Azure File	▮	▮	▮	▮
Azure Disk	▮	▮		
CIFS/SMB	▮	▮	▮	▮
Cinder	▮	▮		
Fibre Channel	▮	▮	▮	▮ [3]
GCP Persistent Disk	▮	▮		
GCP Filestore	▮	▮	▮	▮
HostPath	▮	▮		
IBM Power Virtual Server Disk	▮	▮	▮	▮
IBM Cloud® VPC Disk	▮	▮		
iSCSI	▮	▮	▮	▮ [3]
Local volume	▮	▮		
LVM Storage	▮	▮		

Volume plugin	ReadWriteOnce [1]	ReadWriteOncePod	ReadOnlyMany	ReadWriteMany
NFS	▮	▮	▮	▮
OpenStack Manila		▮		▮
Red Hat OpenShift Data Foundation	▮	▮		▮
VMware vSphere	▮	▮		▮ [4]

1. ReadWriteOnce (RWO) volumes cannot be mounted on multiple nodes. If a node fails, the system does not allow the attached RWO volume to be mounted on a new node because it is already assigned to the failed node. If you encounter a multi-attach error message as a result, force delete the pod on a shutdown or crashed node to avoid data loss in critical workloads, such as when dynamic persistent volumes are attached.

2. Use a recreate deployment strategy for pods that rely on AWS EBS.

3. Only raw block volumes support the ReadWriteMany (RWX) access mode for Fibre Channel and iSCSI. For more information, see "Block volume support".

4. If the underlying vSphere environment supports the vSAN file service, then the vSphere Container Storage Interface (CSI) Driver Operator installed by OpenShift Container Platform supports provisioning of ReadWriteMany (RWX) volumes. If you do not have vSAN file service configured, and you request RWX, the volume fails to get created and an error is logged. For more information, see "Using Container Storage Interface" → "VMware vSphere CSI Driver Operator".

3.3.4. Phase

Volumes can be found in one of the following phases:

Table 3.3. Volume phases

Phase	Description
Available	A free resource not yet bound to a claim.
Bound	The volume is bound to a claim.
Released	The claim was deleted, but the resource is not yet reclaimed by the cluster.
Failed	The volume has failed its automatic reclamation.

3.3.4.1. Last phase transition time

The **LastPhaseTransitionTime** field has a timestamp that updates every time a persistent volume (PV) transitions to a different phase (**pv.Status.Phase**). To find the time of the last phase transition for a PV, run the following command:

```
$ oc get pv <pv-name> -o json | jq '.status.lastPhaseTransitionTime' 1
```

1 Specify the name of the PV that you want to see the last phase transition.

3.3.4.2. Mount options

You can specify mount options while mounting a PV by using the attribute **mountOptions**.

For example:

Mount options example

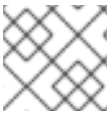
```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: pv0001
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  mountOptions: 1
    - nfsvers=4.1
  nfs:
    path: /tmp
    server: 172.17.0.2
  persistentVolumeReclaimPolicy: Retain
  claimRef:
    name: claim1
    namespace: default
```

1 Specified mount options are used while mounting the PV to the disk.

The following PV types support mount options:

- AWS Elastic Block Store (EBS)
- Azure Disk
- Azure File
- Cinder
- GCE Persistent Disk
- iSCSI
- Local volume

- NFS
- Red Hat OpenShift Data Foundation (Ceph RBD only)
- CIFS/SMB
- VMware vSphere



NOTE

Fibre Channel and HostPath PVs do not support mount options.

Additional resources

- ReadWriteMany vSphere volume support

3.4. PERSISTENT VOLUME CLAIMS

Each **PersistentVolumeClaim** object contains a **spec** and **status**, which is the specification and status of the persistent volume claim (PVC), for example:

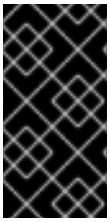
PersistentVolumeClaim object definition example

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: myclaim 1
spec:
  accessModes:
    - ReadWriteOnce 2
  resources:
    requests:
      storage: 8Gi 3
  storageClassName: gold 4
status:
  ...
```

1. Name of the PVC.
2. The access mode, defining the read-write and mount permissions.
3. The amount of storage available to the PVC.
4. Name of the **StorageClass** required by the claim.

3.4.1. Storage classes

Claims can optionally request a specific storage class by specifying the storage class's name in the **storageClassName** attribute. Only PVs of the requested class, ones with the same **storageClassName** as the PVC, can be bound to the PVC. The cluster administrator can configure dynamic provisioners to service one or more storage classes. The cluster administrator can create a PV on demand that matches the specifications in the PVC.



IMPORTANT

The Cluster Storage Operator might install a default storage class depending on the platform in use. This storage class is owned and controlled by the Operator. It cannot be deleted or modified beyond defining annotations and labels. If different behavior is desired, you must define a custom storage class.

The cluster administrator can also set a default storage class for all PVCs. When a default storage class is configured, the PVC must explicitly ask for **StorageClass** or **storageClassName** annotations set to **""** to be bound to a PV without a storage class.

NOTE

If more than one storage class is marked as default, a PVC can only be created if the **storageClassName** is explicitly specified. Therefore, only one storage class should be set as the default.

3.4.2. Access modes

Claims use the same conventions as volumes when requesting storage with specific access modes.

3.4.3. Resources

Claims, such as pods, can request specific quantities of a resource. In this case, the request is for storage. The same resource model applies to volumes and claims.

3.4.4. Claims as volumes

Pods access storage by using the claim as a volume. Claims must exist in the same namespace as the pod using the claim. The cluster finds the claim in the pod's namespace and uses it to get the **PersistentVolume** backing the claim. The volume is mounted to the host and into the pod, for example:

Mount volume to the host and into the pod example

```
kind: Pod
apiVersion: v1
metadata:
  name: mypod
spec:
  containers:
    - name: myfrontend
      image: dockerfile/nginx
      volumeMounts:
      - mountPath: "/var/www/html" 1
        name: mypd 2
  volumes:
    - name: mypd
      persistentVolumeClaim:
        claimName: myclaim 3
```

1 Path to mount the volume inside the pod.

2 Name of the volume to mount. Do not mount to the container root, /, or any path that is the same in the host and the container. This can corrupt your host system if the container is sufficiently

privileged, such as the host **/dev/pts** files. It is safe to mount the host by using **/host**.

3 Name of the PVC, that exists in the same namespace, to use.

3.5. BLOCK VOLUME SUPPORT

OpenShift Container Platform 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.

Raw block volumes are provisioned by specifying **volumeMode: Block** in the PV and PVC specification.

IMPORTANT

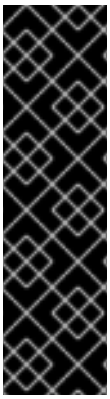
Pods using raw block volumes must be configured to allow privileged containers.

The following table displays which volume plugins support block volumes.

Table 3.4. Block volume support

Volume Plugin	Manually provisioned	Dynamically provisioned	Fully supported
Amazon Elastic Block Store (Amazon EBS)	▮	▮	▮
Amazon Elastic File Storage (Amazon EFS)			
Azure Disk	▮	▮	▮
Azure File			
Cinder	▮	▮	▮
Fibre Channel	▮		▮
GCP	▮	▮	▮
HostPath			
IBM Cloud Block Storage volume	▮	▮	▮
iSCSI	▮		▮
Local volume	▮		▮
LVM Storage	▮	▮	▮

Volume Plugin	Manually provisioned	Dynamically provisioned	Fully supported
NFS			
Red Hat OpenShift Data Foundation	▮	▮	▮
CIFS/SMB	▮	▮	▮
VMware vSphere	▮	▮	▮



IMPORTANT

Using any of the block volumes that can be provisioned manually, but are not provided as fully supported, is a Technology Preview feature only. Technology Preview features are not supported with Red Hat production service level agreements (SLAs) and might not be functionally complete. Red Hat does not recommend using them in production. These features provide early access to upcoming product features, enabling customers to test functionality and provide feedback during the development process.

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

3.5.1. Block volume examples

PV example

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: block-pv
spec:
  capacity:
    storage: 10Gi
  accessModes:
    - ReadWriteOnce
  volumeMode: Block 1
  persistentVolumeReclaimPolicy: Retain
  fc:
    targetWWNs: ["50060e801049cfd1"]
    lun: 0
    readOnly: false
```

1 **volumeMode** must be set to **Block** to indicate that this PV is a raw block volume.

PVC example

```
apiVersion: v1
kind: PersistentVolumeClaim
```

```
metadata:
  name: block-pvc
spec:
  accessModes:
    - ReadWriteOnce
  volumeMode: Block (1)
  resources:
    requests:
      storage: 10Gi
```

1. **volumeMode** must be set to **Block** to indicate that a raw block PVC is requested.

Pod specification example

```
apiVersion: v1
kind: Pod
metadata:
  name: pod-with-block-volume
spec:
  containers:
    - name: fc-container
      image: fedora:26
      command: ["/bin/sh", "-c"]
      args: [ "tail -f /dev/null" ]
      volumeDevices: (1)
        - name: data
          devicePath: /dev/xvda (2)
  volumes:
    - name: data
      persistentVolumeClaim:
        claimName: block-pvc (3)
```

1. **volumeDevices**, instead of **volumeMounts**, is used for block devices. Only **PersistentVolumeClaim** sources can be used with raw block volumes.

2. **devicePath**, instead of **mountPath**, represents the path to the physical device where the raw block is mapped to the system.

3. The volume source must be of type **persistentVolumeClaim** and must match the name of the PVC as expected.

Table 3.5. Accepted values for volumeMode

Value	Default
Filesystem	Yes
Block	No

Table 3.6. Binding scenarios for block volumes

PV volumeMode	PVC volumeMode	Binding result
Filesystem	Filesystem	Bind
Unspecified	Unspecified	Bind
Filesystem	Unspecified	Bind
Unspecified	Filesystem	Bind
Block	Block	Bind
Unspecified	Block	No Bind
Block	Unspecified	No Bind
Filesystem	Block	No Bind
Block	Filesystem	No Bind

IMPORTANT

Unspecified values result in the default value of **Filesystem**.

3.6. USING FSGROUP TO REDUCE POD TIMEOUTS

If a storage volume contains many files (~1,000,000 or greater), you may experience pod timeouts.

This can occur because, by default, OpenShift Container Platform recursively changes ownership and permissions for the contents of each volume to match the **fsGroup** specified in a pod's **securityContext** when that volume is mounted. For large volumes, checking and changing ownership and permissions can be time consuming, slowing pod startup. You can use the **fsGroupChangePolicy** field inside a **securityContext** to control the way that OpenShift Container Platform checks and manages ownership and permissions for a volume.

fsGroupChangePolicy defines behavior for changing ownership and permission of the volume before being exposed inside a pod. This field only applies to volume types that support **fsGroup**-controlled ownership and permissions. This field has two possible values:

- **OnRootMismatch**: Only change permissions and ownership if permission and ownership of root directory does not match with expected permissions of the volume. This can help shorten the time it takes to change ownership and permission of a volume to reduce pod timeouts.
- **Always**: Always change permission and ownership of the volume when a volume is mounted.

fsGroupChangePolicy example

```
securityContext:
  runAsUser: 1000
  runAsGroup: 3000
```

```
fsGroup: 2000
fsGroupChangePolicy: "OnRootMismatch" 1
...
```

1 **OnRootMismatch** specifies skipping recursive permission change, thus helping to avoid pod timeout problems.

NOTE

The fsGroupChangePolicyfield has no effect on ephemeral volume types, such as secret, configMap, and emptydir.

CHAPTER 4. CONFIGURING PERSISTENT STORAGE

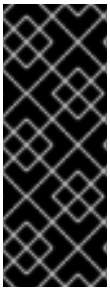
4.1. PERSISTENT STORAGE USING AWS ELASTIC BLOCK STORE

OpenShift Container Platform supports Amazon Elastic Block Store (EBS) volumes. You can provision your OpenShift Container Platform cluster with persistent storage by using Amazon EC2.

The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure. You can dynamically provision Amazon EBS volumes. Persistent volumes are not bound to a single project or namespace; they can be shared across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace and can be requested by users. You can define a KMS key to encrypt container-persistent volumes on AWS. By default, newly created clusters using OpenShift Container Platform version 4.10 and later use gp3 storage and the AWS EBS CSI driver.

IMPORTANT

High-availability of storage in the infrastructure is left to the underlying storage provider.



IMPORTANT

OpenShift Container Platform 4.12 and later provides automatic migration for the AWS Block in-tree volume plugin to its equivalent CSI driver.

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes. For more information about migration, see CSI automatic migration.

4.1.1. Creating the EBS storage class

Storage classes are used to differentiate and delineate storage levels and usages. By defining a storage class, users can obtain dynamically provisioned persistent volumes.

4.1.2. Creating the persistent volume claim

Prerequisites

Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Procedure

1. In the OpenShift Container Platform console, click **Storage → Persistent Volume Claims**
2. In the persistent volume claims overview, click **Create Persistent Volume Claim**
3. Define the desired options on the page that appears.
   a. Select the previously-created storage class from the drop-down menu.
   b. Enter a unique name for the storage claim.

c. Select the access mode. This selection determines the read and write access for the storage claim.

d. Define the size of the storage claim.

4. Click **Create** to create the persistent volume claim and generate a persistent volume.

4.1.3. Volume format

Before OpenShift Container Platform mounts the volume and passes it to a container, it checks that the volume contains a file system as specified by the **fsType** parameter in the persistent volume definition. If the device is not formatted with the file system, all data from the device is erased and the device is automatically formatted with the given file system.

This verification enables you to use unformatted AWS volumes as persistent volumes, because OpenShift Container Platform formats them before the first use.

4.1.4. Maximum number of EBS volumes on a node

By default, OpenShift Container Platform supports a maximum of 39 EBS volumes attached to one node. This limit is consistent with the AWS volume limits. The volume limit depends on the instance type.

IMPORTANT

As a cluster administrator, you must use either in-tree or Container Storage Interface (CSI) volumes and their respective storage classes, but never both volume types at the same time. The maximum attached EBS volume number is counted separately for in-tree and CSI volumes, which means you could have up to 39 EBS volumes of each type.

For information about accessing additional storage options, such as volume snapshots, that are not possible with in-tree volume plug-ins, see AWS Elastic Block Store CSI Driver Operator.

4.1.5. Encrypting container persistent volumes on AWS with a KMS key

Defining a KMS key to encrypt container-persistent volumes on AWS is useful when you have explicit compliance and security guidelines when deploying to AWS.

Prerequisites

- Underlying infrastructure must contain storage.
- You must create a customer KMS key on AWS.

Procedure

1. Create a storage class:

```
$ cat << EOF | oc create -f -
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <storage-class-name> 1
parameters:
  fsType: ext4 2
```

```
  encrypted: "true"
  kmsKeyId: keyvalue 3
provisioner: ebs.csi.aws.com
reclaimPolicy: Delete
volumeBindingMode: WaitForFirstConsumer
EOF
```

1. Specifies the name of the storage class.
2. File system that is created on provisioned volumes.
3. Specifies the full Amazon Resource Name (ARN) of the key to use when encrypting the container-persistent volume. If you do not provide any key, but the **encrypted** field is set to **true**, then the default KMS key is used. See Finding the key ID and key ARN on AWS in the AWS documentation.

2. Create a persistent volume claim (PVC) with the storage class specifying the KMS key:

```
$ cat << EOF | oc create -f -
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: mypvc
spec:
  accessModes:
    - ReadWriteOnce
  volumeMode: Filesystem
  storageClassName: <storage-class-name>
  resources:
    requests:
      storage: 1Gi
EOF
```

3. Create workload containers to consume the PVC:

```
$ cat << EOF | oc create -f -
kind: Pod
metadata:
  name: mypod
spec:
  containers:
    - name: httpd
      image: quay.io/centos7/httpd-24-centos7
      ports:
        - containerPort: 80
      volumeMounts:
        - mountPath: /mnt/storage
          name: data
  volumes:
    - name: data
      persistentVolumeClaim:
        claimName: mypvc
EOF
```

4.1.6. Additional resources

- See AWS Elastic Block Store CSI Driver Operator for information about accessing additional storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

4.2. PERSISTENT STORAGE USING AZURE

OpenShift Container Platform supports Microsoft Azure Disk volumes. You can provision your OpenShift Container Platform cluster with persistent storage using Azure. Some familiarity with Kubernetes and Azure is assumed. The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure. Azure Disk volumes can be provisioned dynamically. Persistent volumes are not bound to a single project or namespace; they can be shared across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace and can be requested by users.

IMPORTANT

OpenShift Container Platform 4.11 and later provides automatic migration for the Azure Disk in-tree volume plugin to its equivalent CSI driver.

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes. For more information about migration, see CSI automatic migration .

IMPORTANT

High availability of storage in the infrastructure is left to the underlying storage provider.

Additional resources

- Microsoft Azure Disk

4.2.1. Creating the Azure storage class

Storage classes are used to differentiate and delineate storage levels and usages. By defining a storage class, users can obtain dynamically provisioned persistent volumes.

Procedure

1. In the OpenShift Container Platform console, click **Storage → Storage Classes**.
2. In the storage class overview, click **Create Storage Class**
3. Define the desired options on the page that appears.
   a. Enter a name to reference the storage class.
   b. Enter an optional description.
   c. Select the reclaim policy.
   d. Select **kubernetes.io/azure-disk** from the drop down list.

i. Enter the storage account type. This corresponds to your Azure storage account SKU tier. Valid options are **Premium_LRS**, **PremiumV2_LRS**, **Standard_LRS**, **StandardSSD_LRS**, and **UltraSSD_LRS**.

IMPORTANT

The skuname **PremiumV2_LRS** is not supported in all regions, and in some supported regions, not all of the availability zones are supported. For more information, see Azure doc.

ii. Enter the kind of account. Valid options are **shared**, **dedicated,** and **managed**.

IMPORTANT

Red Hat only supports the use of **kind: Managed** in the storage class.

With **Shared** and **Dedicated**, Azure creates unmanaged disks, while OpenShift Container Platform creates a managed disk for machine OS (root) disks. But because Azure Disk does not allow the use of both managed and unmanaged disks on a node, unmanaged disks created with **Shared** or **Dedicated** cannot be attached to OpenShift Container Platform nodes.

e. Enter additional parameters for the storage class as desired.

4. Click **Create** to create the storage class.

Additional resources

- Azure Disk Storage Class

4.2.2. Creating the persistent volume claim

Prerequisites

Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Procedure

1. In the OpenShift Container Platform console, click **Storage → Persistent Volume Claims**
2. In the persistent volume claims overview, click **Create Persistent Volume Claim**
3. Define the desired options on the page that appears.
   a. Select the previously-created storage class from the drop-down menu.
   b. Enter a unique name for the storage claim.
   c. Select the access mode. This selection determines the read and write access for the storage claim.
   d. Define the size of the storage claim.

4. Click **Create** to create the persistent volume claim and generate a persistent volume.

4.2.3. Volume format

Before OpenShift Container Platform mounts the volume and passes it to a container, it checks that it contains a file system as specified by the **fsType** parameter in the persistent volume definition. If the device is not formatted with the file system, all data from the device is erased and the device is automatically formatted with the given file system.

This allows using unformatted Azure volumes as persistent volumes, because OpenShift Container Platform formats them before the first use.

4.2.4. Machine sets that deploy machines with ultra disks using PVCs

You can create a machine set running on Azure that deploys machines with ultra disks. Ultra disks are high-performance storage that are intended for use with the most demanding data workloads.

Both the in-tree plugin and CSI driver support using PVCs to enable ultra disks. You can also deploy machines with ultra disks as data disks without creating a PVC.

Additional resources

- Microsoft Azure ultra disks documentation
- Machine sets that deploy machines on ultra disks using CSI PVCs
- Machine sets that deploy machines on ultra disks as data disks

4.2.4.1. Creating machines with ultra disks by using machine sets

You can deploy machines with ultra disks on Azure by editing your machine set YAML file.

Prerequisites

- Have an existing Microsoft Azure cluster.

Procedure

1. Copy an existing Azure **MachineSet** custom resource (CR) and edit it by running the following command:

```
$ oc edit machineset <machine_set_name>
```

   where **<machine_set_name>** is the machine set that you want to provision machines with ultra disks.

2. Add the following lines in the positions indicated:

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
spec:
  template:
    spec:
      metadata:
```

```
      labels:
        disk: ultrassd 1
    providerSpec:
      value:
        ultraSSDCapability: Enabled 2
```

1. Specify a label to use to select a node that is created by this machine set. This procedure uses **disk.ultrassd** for this value.
2. These lines enable the use of ultra disks.

3. Create a machine set using the updated configuration by running the following command:

```
$ oc create -f <machine_set_name>.yaml
```

4. Create a storage class that contains the following YAML definition:

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: ultra-disk-sc 1
parameters:
  cachingMode: None
  diskIopsReadWrite: "2000" 2
  diskMbpsReadWrite: "320" 3
  kind: managed
  skuname: UltraSSD_LRS
provisioner: disk.csi.azure.com 4
reclaimPolicy: Delete
volumeBindingMode: WaitForFirstConsumer 5
```

1. Specify the name of the storage class. This procedure uses **ultra-disk-sc** for this value.
2. Specify the number of IOPS for the storage class.
3. Specify the throughput in MBps for the storage class.
4. For Azure Kubernetes Service (AKS) version 1.21 or later, use **disk.csi.azure.com**. For earlier versions of AKS, use **kubernetes.io/azure-disk**.
5. Optional: Specify this parameter to wait for the creation of the pod that will use the disk.

5. Create a persistent volume claim (PVC) to reference the **ultra-disk-sc** storage class that contains the following YAML definition:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: ultra-disk 1
spec:
  accessModes:
  - ReadWriteOnce
  storageClassName: ultra-disk-sc 2
```

```
  resources:
    requests:
      storage: 4Gi 3
```

1. Specify the name of the PVC. This procedure uses **ultra-disk** for this value.
2. This PVC references the **ultra-disk-sc** storage class.
3. Specify the size for the storage class. The minimum value is **4Gi**.

6. Create a pod that contains the following YAML definition:

```
apiVersion: v1
kind: Pod
metadata:
  name: nginx-ultra
spec:
  nodeSelector:
    disk: ultrassd 1
  containers:
  - name: nginx-ultra
    image: alpine:latest
    command:
      - "sleep"
      - "infinity"
    volumeMounts:
    - mountPath: "/mnt/azure"
      name: volume
  volumes:
    - name: volume
      persistentVolumeClaim:
        claimName: ultra-disk 2
```

1. Specify the label of the machine set that enables the use of ultra disks. This procedure uses **disk.ultrassd** for this value.
2. This pod references the **ultra-disk** PVC.

Verification

1. Validate that the machines are created by running the following command:

```
$ oc get machines
```

The machines should be in the **Running** state.

2. For a machine that is running and has a node attached, validate the partition by running the following command:

```
$ oc debug node/<node_name> -- chroot /host lsblk
```

In this command, **oc debug node/<node_name>** starts a debugging shell on the node **<node_name>** and passes a command with **--**. The passed command **chroot /host** provides

access to the underlying host OS binaries, and **lsblk** shows the block devices that are attached to the host OS machine.

Next steps

- To use an ultra disk from within a pod, create a workload that uses the mount point. Create a YAML file similar to the following example:

```
apiVersion: v1
kind: Pod
metadata:
  name: ssd-benchmark1
spec:
  containers:
  - name: ssd-benchmark1
    image: nginx
    ports:
      - containerPort: 80
        name: "http-server"
    volumeMounts:
    - name: lun0p1
      mountPath: "/tmp"
  volumes:
    - name: lun0p1
      hostPath:
        path: /var/lib/lun0p1
        type: DirectoryOrCreate
  nodeSelector:
    disktype: ultrassd
```

4.2.4.2. Troubleshooting resources for machine sets that enable ultra disks

Use the information in this section to understand and recover from issues you might encounter.

4.2.4.2.1. Unable to mount a persistent volume claim backed by an ultra disk

If there is an issue mounting a persistent volume claim backed by an ultra disk, the pod becomes stuck in the **ContainerCreating** state and an alert is triggered.

For example, if the **additionalCapabilities.ultraSSDEnabled** parameter is not set on the machine that backs the node that hosts the pod, the following error message appears:

```
StorageAccountType UltraSSD_LRS can be used only when additionalCapabilities.ultraSSDEnabled is set.
```

- To resolve this issue, describe the pod by running the following command:

```
$ oc -n <stuck_pod_namespace> describe pod <stuck_pod_name>
```

4.3. PERSISTENT STORAGE USING AZURE FILE

OpenShift Container Platform supports Microsoft Azure File volumes. You can provision your OpenShift Container Platform cluster with persistent storage using Azure. Some familiarity with Kubernetes and Azure is assumed.

The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure. You can provision Azure File volumes dynamically.

Persistent volumes are not bound to a single project or namespace, and you can share them across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace, and can be requested by users for use in applications.

IMPORTANT

High availability of storage in the infrastructure is left to the underlying storage provider.

IMPORTANT

Azure File volumes use Server Message Block.

IMPORTANT

OpenShift Container Platform 4.13 and later provides automatic migration for the Azure File in-tree volume plugin to its equivalent CSI driver.

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes. For more information about migration, see CSI automatic migration .

Additional resources

- Azure Files

4.3.1. Create the Azure File share persistent volume claim

To create the persistent volume claim, you must first define a **Secret** object that contains the Azure account and key. This secret is used in the **PersistentVolume** definition, and will be referenced by the persistent volume claim for use in applications.

Prerequisites

- An Azure File share exists.
- The credentials to access this share, specifically the storage account and key, are available.

Procedure

1. Create a **Secret** object that contains the Azure File credentials:

```
$ oc create secret generic <secret-name> --from-literal=azurestorageaccountname=
<storage-account> \ 1
  --from-literal=azurestorageaccountkey=<storage-account-key> 2
```

1 The Azure File storage account name.

2 The Azure File storage account key.

2. Create a **PersistentVolume** object that references the **Secret** object you created:

```
apiVersion: "v1"
kind: "PersistentVolume"
metadata:
  name: "pv0001" 1
spec:
  capacity:
    storage: "5Gi" 2
  accessModes:
    - "ReadWriteOnce"
  storageClassName: azure-file-sc
  azureFile:
    secretName: <secret-name> 3
    shareName: share-1 4
    readOnly: false
```

1 The name of the persistent volume.

2 The size of this persistent volume.

3 The name of the secret that contains the Azure File share credentials.

4 The name of the Azure File share.

3. Create a **PersistentVolumeClaim** object that maps to the persistent volume you created:

```
apiVersion: "v1"
kind: "PersistentVolumeClaim"
metadata:
  name: "claim1" 1
spec:
  accessModes:
    - "ReadWriteOnce"
  resources:
    requests:
      storage: "5Gi" 2
  storageClassName: azure-file-sc 3
  volumeName: "pv0001" 4
```

1 The name of the persistent volume claim.

2 The size of this persistent volume claim.

3 The name of the storage class that is used to provision the persistent volume. Specify the storage class used in the **PersistentVolume** definition.

4 The name of the existing **PersistentVolume** object that references the Azure File share.

4.3.2. Mount the Azure File share in a pod

After the persistent volume claim has been created, it can be used inside by an application. The following example demonstrates mounting this share inside of a pod.

Prerequisites

- A persistent volume claim exists that is mapped to the underlying Azure File share.

Procedure

- Create a pod that mounts the existing persistent volume claim:

```
apiVersion: v1
kind: Pod
metadata:
  name: pod-name (1)
spec:
  containers:
    ...
    volumeMounts:
    - mountPath: "/data" (2)
      name: azure-file-share
  volumes:
    - name: azure-file-share
      persistentVolumeClaim:
        claimName: claim1 (3)
```

(1) The name of the pod.

(2) The path to mount the Azure File share inside the pod. Do not mount to the container root, /, or any path that is the same in the host and the container. This can corrupt your host system if the container is sufficiently privileged, such as the host **/dev/pts** files. It is safe to mount the host by using **/host**.

(3) The name of the **PersistentVolumeClaim** object that has been previously created.

4.4. PERSISTENT STORAGE USING CINDER

OpenShift Container Platform supports OpenStack Cinder. Some familiarity with Kubernetes and OpenStack is assumed.

Cinder volumes can be provisioned dynamically. Persistent volumes are not bound to a single project or namespace; they can be shared across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace and can be requested by users.

IMPORTANT

OpenShift Container Platform 4.11 and later provides automatic migration for the Cinder in-tree volume plugin to its equivalent CSI driver.

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes. For more information about migration, see CSI automatic migration .

Additional resources

- For more information about how OpenStack Block Storage provides persistent block storage management for virtual hard drives, see OpenStack Cinder.

4.4.1. Manual provisioning with Cinder

Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Prerequisites

- OpenShift Container Platform configured for Red Hat OpenStack Platform (RHOSP)
- Cinder volume ID

4.4.1.1. Creating the persistent volume

You must define your persistent volume (PV) in an object definition before creating it in OpenShift Container Platform:

Procedure

1. Save your object definition to a file.

   cinder-persistentvolume.yaml

```
apiVersion: "v1"
kind: "PersistentVolume"
metadata:
  name: "pv0001" 1
spec:
  capacity:
    storage: "5Gi" 2
  accessModes:
    - "ReadWriteOnce"
  cinder: 3
    fsType: "ext3" 4
    volumeID: "f37a03aa-6212-4c62-a805-9ce139fab180" 5
```

1. The name of the volume that is used by persistent volume claims or pods.
2. The amount of storage allocated to this volume.
3. Indicates **cinder** for Red Hat OpenStack Platform (RHOSP) Cinder volumes.
4. The file system that is created when the volume is mounted for the first time.
5. The Cinder volume to use.

IMPORTANT

Do not change the **fstype** parameter value after the volume is formatted and provisioned. Changing this value can result in data loss and pod failure.

2. Create the object definition file you saved in the previous step.

```
$ oc create -f cinder-persistentvolume.yaml
```

4.4.1.2. Persistent volume formatting

You can use unformatted Cinder volumes as PVs because OpenShift Container Platform formats them before the first use.

Before OpenShift Container Platform mounts the volume and passes it to a container, the system checks that it contains a file system as specified by the **fsType** parameter in the PV definition. If the device is not formatted with the file system, all data from the device is erased and the device is automatically formatted with the given file system.

4.4.1.3. Cinder volume security

If you use Cinder PVs in your application, configure security for their deployment configurations.

Prerequisites

- An SCC must be created that uses the appropriate **fsGroup** strategy.

Procedure

1. Create a service account and add it to the SCC:

```
$ oc create serviceaccount <service_account>
```

```
$ oc adm policy add-scc-to-user <new_scc> -z <service_account> -n <project>
```

2. In your application's deployment configuration, provide the service account name and **securityContext**:

```
apiVersion: v1
kind: ReplicationController
metadata:
  name: frontend-1
spec:
  replicas: 1 1
  selector: 2
    name: frontend
  template: 3
    metadata:
      labels: 4
        name: frontend 5
    spec:
      containers:
      - image: openshift/hello-openshift
```

```
      name: helloworld
      ports:
      - containerPort: 8080
        protocol: TCP
    restartPolicy: Always
    serviceAccountName: <service_account> 6
    securityContext:
      fsGroup: 7777 7
```

1. The number of copies of the pod to run.
2. The label selector of the pod to run.
3. A template for the pod that the controller creates.
4. The labels on the pod. They must include labels from the label selector.
5. The maximum name length after expanding any parameters is 63 characters.
6. Specifies the service account you created.
7. Specifies an **fsGroup** for the pods.

4.5. PERSISTENT STORAGE USING FIBRE CHANNEL

OpenShift Container Platform supports Fibre Channel, allowing you to provision your OpenShift Container Platform cluster with persistent storage using Fibre channel volumes. Some familiarity with Kubernetes and Fibre Channel is assumed.

IMPORTANT

Persistent storage using Fibre Channel is not supported on ARM architecture based infrastructures.

The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure. Persistent volumes are not bound to a single project or namespace; they can be shared across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace and can be requested by users.

IMPORTANT

High availability of storage in the infrastructure is left to the underlying storage provider.

Additional resources

- Using Fibre Channel devices

4.5.1. Provisioning

To provision Fibre Channel volumes using the **PersistentVolume** API the following must be available:

- The **targetWWNs** (array of Fibre Channel target's World Wide Names).

- A valid LUN number.
- The filesystem type.

A persistent volume and a LUN have a one-to-one mapping between them.

Prerequisites

- Fibre Channel LUNs must exist in the underlying infrastructure.

PersistentVolume object definition

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: pv0001
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  fc:
    wwids: [scsi-3600508b400105e210000900000490000] 1
    targetWWNs: ['500a0981891b8dc5', '500a0981991b8dc5'] 2
    lun: 2 3
    fsType: ext4
```

1 World wide identifiers (WWIDs). Either FC **wwids** or a combination of FC **targetWWNs** and **lun** must be set, but not both simultaneously. The FC WWID identifier is recommended over the WWNs target because it is guaranteed to be unique for every storage device, and independent of the path that is used to access the device. The WWID identifier can be obtained by issuing a SCSI Inquiry to retrieve the Device Identification Vital Product Data (**page 0x83**) or Unit Serial Number (**page 0x80**). FC WWIDs are identified as **/dev/disk/by-id/** to reference the data on the disk, even if the path to the device changes and even when accessing the device from different systems.

2 3 Fibre Channel WWNs are identified as **/dev/disk/by-path/pci-<IDENTIFIER>-fc-0x<WWN>-lun-<LUN#>**, but you do not need to provide any part of the path leading up to the **WWN**, including the **0x**, and anything after, including the **-** (hyphen).

IMPORTANT

Changing the value of the **fstype** parameter after the volume has been formatted and provisioned can result in data loss and pod failure.

4.5.1.1. Enforcing disk quotas

Use LUN partitions to enforce disk quotas and size constraints. Each LUN is mapped to a single persistent volume, and unique names must be used for persistent volumes.

Enforcing quotas in this way allows the end user to request persistent storage by a specific amount, such as 10Gi, and be matched with a corresponding volume of equal or greater capacity.

4.5.1.2. Fibre Channel volume security

Users request storage with a persistent volume claim. This claim only lives in the user's namespace, and can only be referenced by a pod within that same namespace. Any attempt to access a persistent volume across a namespace causes the pod to fail.

Each Fibre Channel LUN must be accessible by all nodes in the cluster.

4.6. PERSISTENT STORAGE USING FLEXVOLUME

IMPORTANT

FlexVolume is a deprecated feature. Deprecated functionality is still included in OpenShift Container Platform and continues to be supported; however, it will be removed in a future release of this product and is not recommended for new deployments.

Out-of-tree Container Storage Interface (CSI) driver is the recommended way to write volume drivers in OpenShift Container Platform. Maintainers of FlexVolume drivers should implement a CSI driver and move users of FlexVolume to CSI. Users of FlexVolume should move their workloads to CSI driver.

For the most recent list of major functionality that has been deprecated or removed within OpenShift Container Platform, refer to the *Deprecated and removed features* section of the OpenShift Container Platform release notes.

OpenShift Container Platform supports FlexVolume, an out-of-tree plugin that uses an executable model to interface with drivers.

To use storage from a back-end that does not have a built-in plugin, you can extend OpenShift Container Platform through FlexVolume drivers and provide persistent storage to applications.

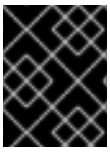
Pods interact with FlexVolume drivers through the **flexvolume** in-tree plugin.

Additional resources

- Expanding persistent volumes

4.6.1. About FlexVolume drivers

A FlexVolume driver is an executable file that resides in a well-defined directory on all nodes in the cluster. OpenShift Container Platform calls the FlexVolume driver whenever it needs to mount or unmount a volume represented by a **PersistentVolume** object with **flexVolume** as the source.



IMPORTANT

Attach and detach operations are not supported in OpenShift Container Platform for FlexVolume.

4.6.2. FlexVolume driver example

The first command-line argument of the FlexVolume driver is always an operation name. Other parameters are specific to each operation. Most of the operations take a JavaScript Object Notation (JSON) string as a parameter. This parameter is a complete JSON string, and not the name of a file with the JSON data.

The FlexVolume driver contains:

- All **flexVolume.options**.
- Some options from **flexVolume** prefixed by **kubernetes.io/**, such as **fsType** and **readwrite**.
- The content of the referenced secret, if specified, prefixed by **kubernetes.io/secret/**.

FlexVolume driver JSON input example

```
{
 "fooServer": "192.168.0.1:1234", (1)
       "fooVolumeName": "bar",
 "kubernetes.io/fsType": "ext4", (2)
 "kubernetes.io/readwrite": "ro", (3)
 "kubernetes.io/secret/<key name>": "<key value>", (4)
 "kubernetes.io/secret/<another key name>": "<another key value>",
}
```

1. All options from **flexVolume.options**.
2. The value of **flexVolume.fsType**.
3. **ro**/**rw** based on **flexVolume.readOnly**.
4. All keys and their values from the secret referenced by **flexVolume.secretRef**.

OpenShift Container Platform expects JSON data on standard output of the driver. When not specified, the output describes the result of the operation.

FlexVolume driver default output example

```
{
 "status": "<Success/Failure/Not supported>",
 "message": "<Reason for success/failure>"
}
```

Exit code of the driver should be **0** for success and **1** for error.

Operations should be idempotent, which means that the mounting of an already mounted volume should result in a successful operation.

4.6.3. Installing FlexVolume drivers

FlexVolume drivers that are used to extend OpenShift Container Platform are executed only on the node. To implement FlexVolumes, a list of operations to call and the installation path are all that is required.

Prerequisites

- FlexVolume drivers must implement these operations:

  init

Initializes the driver. It is called during initialization of all nodes.

- Arguments: none
- Executed on: node
- Expected output: default JSON

mount

Mounts a volume to directory. This can include anything that is necessary to mount the volume, including finding the device and then mounting the device.

- Arguments: **<mount-dir> <json>**
- Executed on: node
- Expected output: default JSON

unmount

Unmounts a volume from a directory. This can include anything that is necessary to clean up the volume after unmounting.

- Arguments: **<mount-dir>**
- Executed on: node
- Expected output: default JSON

mountdevice

Mounts a volume's device to a directory where individual pods can then bind mount.

This call-out does not pass "secrets" specified in the FlexVolume spec. If your driver requires secrets, do not implement this call-out.

- Arguments: **<mount-dir> <json>**
- Executed on: node
- Expected output: default JSON

unmountdevice

Unmounts a volume's device from a directory.

- Arguments: **<mount-dir>**
- Executed on: node
- Expected output: default JSON
  - All other operations should return JSON with **{"status": "Not supported"}** and exit code **1**.

Procedure

To install the FlexVolume driver:

1. Ensure that the executable file exists on all nodes in the cluster.

2. Place the executable file at the volume plugin path: **/etc/kubernetes/kubelet-plugins/volume/exec/<vendor>~<driver>/<driver>**.

For example, to install the FlexVolume driver for the storage **foo**, place the executable file at: **/etc/kubernetes/kubelet-plugins/volume/exec/openshift.com~foo/foo**.

4.6.4. Consuming storage using FlexVolume drivers

Each **PersistentVolume** object in OpenShift Container Platform represents one storage asset in the storage back-end, such as a volume.

Procedure

- Use the **PersistentVolume** object to reference the installed storage.

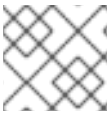
Persistent volume object definition using FlexVolume drivers example

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: pv0001 1
spec:
  capacity:
    storage: 1Gi 2
  accessModes:
    - ReadWriteOnce
  flexVolume:
    driver: openshift.com/foo 3
    fsType: "ext4" 4
    secretRef: foo-secret 5
    readOnly: true 6
    options: 7
      fooServer: 192.168.0.1:1234
      fooVolumeName: bar
```

1. The name of the volume. This is how it is identified through persistent volume claims or from pods. This name can be different from the name of the volume on back-end storage.
2. The amount of storage allocated to this volume.
3. The name of the driver. This field is mandatory.
4. The file system that is present on the volume. This field is optional.
5. The reference to a secret. Keys and values from this secret are provided to the FlexVolume driver on invocation. This field is optional.
6. The read-only flag. This field is optional.
7. The additional options for the FlexVolume driver. In addition to the flags specified by the user in the **options** field, the following flags are also passed to the executable:

```
"fsType":"<FS type>",
"readwrite":"<rw>",
```

```
"secret/key1":"<secret1>"
...
"secret/keyN":"<secretN>"
```



NOTE

Secrets are passed only to mount or unmount call-outs.

4.7. PERSISTENT STORAGE USING GCE PERSISTENT DISK

OpenShift Container Platform supports GCE Persistent Disk volumes (gcePD). You can provision your OpenShift Container Platform cluster with persistent storage using GCE. Some familiarity with Kubernetes and GCE is assumed.

The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure.

GCE Persistent Disk volumes can be provisioned dynamically.

Persistent volumes are not bound to a single project or namespace; they can be shared across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace and can be requested by users.

IMPORTANT

OpenShift Container Platform 4.12 and later provides automatic migration for the GCE Persist Disk in-tree volume plugin to its equivalent CSI driver.

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes.

For more information about migration, see CSI automatic migration .

IMPORTANT

High availability of storage in the infrastructure is left to the underlying storage provider.

Additional resources

- GCE Persistent Disk

4.7.1. Creating the GCE storage class

Storage classes are used to differentiate and delineate storage levels and usages. By defining a storage class, users can obtain dynamically provisioned persistent volumes.

4.7.2. Creating the persistent volume claim

Prerequisites

Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Procedure

1. In the OpenShift Container Platform console, click **Storage → Persistent Volume Claims**
2. In the persistent volume claims overview, click **Create Persistent Volume Claim**
3. Define the desired options on the page that appears.
   a. Select the previously-created storage class from the drop-down menu.
   b. Enter a unique name for the storage claim.
   c. Select the access mode. This selection determines the read and write access for the storage claim.
   d. Define the size of the storage claim.
4. Click **Create** to create the persistent volume claim and generate a persistent volume.

4.7.3. Volume format

Before OpenShift Container Platform mounts the volume and passes it to a container, it checks that the volume contains a file system as specified by the **fsType** parameter in the persistent volume definition. If the device is not formatted with the file system, all data from the device is erased and the device is automatically formatted with the given file system.

This verification enables you to use unformatted GCE volumes as persistent volumes, because OpenShift Container Platform formats them before the first use.

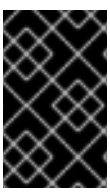
4.8. PERSISTENT STORAGE USING ISCSI

You can provision your OpenShift Container Platform cluster with persistent storage using iSCSI. Some familiarity with Kubernetes and iSCSI is assumed.

The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure.

IMPORTANT

High-availability of storage in the infrastructure is left to the underlying storage provider.



IMPORTANT

When you use iSCSI on Amazon Web Services, you must update the default security policy to include TCP traffic between nodes on the iSCSI ports. By default, they are ports **860** and **3260**.

IMPORTANT

Users must ensure that the iSCSI initiator is already configured on all OpenShift Container Platform nodes by installing the **iscsi-initiator-utils** package and configuring their initiator name in **/etc/iscsi/initiatorname.iscsi**. The **iscsi-initiator-utils** package is already installed on deployments that use Red Hat Enterprise Linux CoreOS (RHCOS).

For more information, see Managing Storage Devices.

4.8.1. Provisioning

Verify that the storage exists in the underlying infrastructure before mounting it as a volume in OpenShift Container Platform. All that is required for the iSCSI is the iSCSI target portal, a valid iSCSI Qualified Name (IQN), a valid LUN number, the filesystem type, and the **PersistentVolume** API.

PersistentVolume object definition

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: iscsi-pv
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  iscsi:
    targetPortal: 10.16.154.81:3260
    iqn: iqn.2014-12.example.server:storage.target00
    lun: 0
    fsType: 'ext4'
```

4.8.2. Enforcing disk quotas

Use LUN partitions to enforce disk quotas and size constraints. Each LUN is one persistent volume. Kubernetes enforces unique names for persistent volumes.

Enforcing quotas in this way allows the end user to request persistent storage by a specific amount (for example, **10Gi**) and be matched with a corresponding volume of equal or greater capacity.

4.8.3. iSCSI volume security

Users request storage with a **PersistentVolumeClaim** object. This claim only lives in the user's namespace and can only be referenced by a pod within that same namespace. Any attempt to access a persistent volume claim across a namespace causes the pod to fail.

Each iSCSI LUN must be accessible by all nodes in the cluster.

4.8.3.1. Challenge Handshake Authentication Protocol (CHAP) configuration

Optionally, OpenShift Container Platform can use CHAP to authenticate itself to iSCSI targets:

```
apiVersion: v1
kind: PersistentVolume
```

```
metadata:
  name: iscsi-pv
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  iscsi:
    targetPortal: 10.0.0.1:3260
    iqn: iqn.2016-04.test.com:storage.target00
    lun: 0
    fsType: ext4
    chapAuthDiscovery: true (1)
    chapAuthSession: true (2)
    secretRef:
      name: chap-secret (3)
```

1. Enable CHAP authentication of iSCSI discovery.
2. Enable CHAP authentication of iSCSI session.
3. Specify name of Secrets object with user name + password. This **Secret** object must be available in all namespaces that can use the referenced volume.

4.8.4. iSCSI multipathing

For iSCSI-based storage, you can configure multiple paths by using the same IQN for more than one target portal IP address. Multipathing ensures access to the persistent volume when one or more of the components in a path fail.

To specify multi-paths in the pod specification, use the **portals** field. For example:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: iscsi-pv
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  iscsi:
    targetPortal: 10.0.0.1:3260
    portals: ['10.0.2.16:3260', '10.0.2.17:3260', '10.0.2.18:3260'] (1)
    iqn: iqn.2016-04.test.com:storage.target00
    lun: 0
    fsType: ext4
    readOnly: false
```

1. Add additional target portals using the **portals** field.

4.8.5. iSCSI custom initiator IQN

Configure the custom initiator iSCSI Qualified Name (IQN) if the iSCSI targets are restricted to certain IQNs, but the nodes that the iSCSI PVs are attached to are not guaranteed to have these IQNs.

To specify a custom initiator IQN, use **initiatorName** field.

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: iscsi-pv
spec:
  capacity:
    storage: 1Gi
  accessModes:
    - ReadWriteOnce
  iscsi:
    targetPortal: 10.0.0.1:3260
    portals: ['10.0.2.16:3260', '10.0.2.17:3260', '10.0.2.18:3260']
    iqn: iqn.2016-04.test.com:storage.target00
    lun: 0
    initiatorName: iqn.2016-04.test.com:custom.iqn (1)
    fsType: ext4
    readOnly: false
```

1 Specify the name of the initiator.

4.9. PERSISTENT STORAGE USING NFS

OpenShift Container Platform clusters can be provisioned with persistent storage using NFS. Persistent volumes (PVs) and persistent volume claims (PVCs) provide a convenient method for sharing a volume across a project. While the NFS-specific information contained in a PV definition could also be defined directly in a **Pod** definition, doing so does not create the volume as a distinct cluster resource, making the volume more susceptible to conflicts.

Additional resources

- Mounting NFS shares

4.9.1. Provisioning

Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform. To provision NFS volumes, a list of NFS servers and export paths are all that is required.

Procedure

1. Create an object definition for the PV:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: pv0001 (1)
spec:
  capacity:
```

```
    storage: 5Gi (2)
  accessModes:
  - ReadWriteOnce (3)
  nfs: (4)
    path: /tmp (5)
    server: 172.17.0.2 (6)
  persistentVolumeReclaimPolicy: Retain (7)
```

1. The name of the volume. This is the PV identity in various **oc <command> pod** commands.
2. The amount of storage allocated to this volume.
3. Though this appears to be related to controlling access to the volume, it is actually used similarly to labels and used to match a PVC to a PV. Currently, no access rules are enforced based on the **accessModes**.
4. The volume type being used, in this case the **nfs** plugin.
5. The path that is exported by the NFS server.
6. The hostname or IP address of the NFS server.
7. The reclaim policy for the PV. This defines what happens to a volume when released.

NOTE

Each NFS volume must be mountable by all schedulable nodes in the cluster.

2. Verify that the PV was created:

```
$ oc get pv
```

Example output

```
NAME    LABELS    CAPACITY    ACCESSMODES   STATUS      CLAIM   REASON   AGE
pv0001  <none>    5Gi         RWO           Available                    31s
```

3. Create a persistent volume claim that binds to the new PV:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: nfs-claim1
spec:
  accessModes:
    - ReadWriteOnce (1)
  resources:
    requests:
      storage: 5Gi (2)
  volumeName: pv0001
  storageClassName: ""
```

1. The access modes do not enforce security, but rather act as labels to match a PV to a PVC.
2. This claim looks for PVs offering **5Gi** or greater capacity.

4. Verify that the persistent volume claim was created:

```
$ oc get pvc
```

Example output

```
NAME         STATUS   VOLUME   CAPACITY   ACCESS MODES   STORAGECLASS   AGE
nfs-claim1   Bound    pv0001   5Gi        RWO                           2m
```

4.9.2. Enforcing disk quotas

You can use disk partitions to enforce disk quotas and size constraints. Each partition can be its own export. Each export is one PV. OpenShift Container Platform enforces unique names for PVs, but the uniqueness of the NFS volume's server and path is up to the administrator.

Enforcing quotas in this way allows the developer to request persistent storage by a specific amount, such as 10Gi, and be matched with a corresponding volume of equal or greater capacity.

4.9.3. NFS volume security

This section covers NFS volume security, including matching permissions and SELinux considerations. The user is expected to understand the basics of POSIX permissions, process UIDs, supplemental groups, and SELinux.

Developers request NFS storage by referencing either a PVC by name or the NFS volume plugin directly in the **volumes** section of their **Pod** definition.

The **/etc/exports** file on the NFS server contains the accessible NFS directories. The target NFS directory has POSIX owner and group IDs. The OpenShift Container Platform NFS plugin mounts the container's NFS directory with the same POSIX ownership and permissions found on the exported NFS directory. However, the container is not run with its effective UID equal to the owner of the NFS mount, which is the desired behavior.

As an example, if the target NFS directory appears on the NFS server as:

```
$ ls -lZ /opt/nfs -d
```

Example output

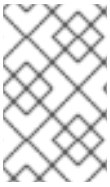
```
drwxrws---. nfsnobody 5555 unconfined_u:object_r:usr_t:s0   /opt/nfs
```

```
$ id nfsnobody
```

Example output

```
uid=65534(nfsnobody) gid=65534(nfsnobody) groups=65534(nfsnobody)
```

Then the container must match SELinux labels, and either run with a UID of **65534**, the **nfsnobody** owner, or with **5555** in its supplemental groups to access the directory.

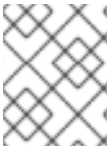


NOTE

The owner ID of **65534** is used as an example. Even though NFS's **root_squash** maps **root**, uid **0**, to **nfsnobody**, uid **65534**, NFS exports can have arbitrary owner IDs. Owner **65534** is not required for NFS exports.

4.9.3.1. Group IDs

The recommended way to handle NFS access, assuming it is not an option to change permissions on the NFS export, is to use supplemental groups. Supplemental groups in OpenShift Container Platform are used for shared storage, of which NFS is an example. In contrast, block storage such as iSCSI uses the **fsGroup** SCC strategy and the **fsGroup** value in the **securityContext** of the pod.



NOTE

To gain access to persistent storage, it is generally preferable to use supplemental group IDs versus user IDs.

Because the group ID on the example target NFS directory is **5555**, the pod can define that group ID using **supplementalGroups** under the **securityContext** definition of the pod. For example:

```
spec:
  containers:
    - name:
    ...
  securityContext: 1
    supplementalGroups: [5555] 2
```

1 **securityContext** must be defined at the pod level, not under a specific container.

2 An array of GIDs defined for the pod. In this case, there is one element in the array. Additional GIDs would be comma-separated.

Assuming there are no custom SCCs that might satisfy the pod requirements, the pod likely matches the **restricted** SCC. This SCC has the **supplementalGroups** strategy set to **RunAsAny**, meaning that any supplied group ID is accepted without range checking.

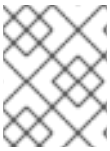
As a result, the above pod passes admissions and is launched. However, if group ID range checking is desired, a custom SCC is the preferred solution. A custom SCC can be created such that minimum and maximum group IDs are defined, group ID range checking is enforced, and a group ID of **5555** is allowed.

NOTE

To use a custom SCC, you must first add it to the appropriate service account. For example, use the **default** service account in the given project unless another has been specified on the **Pod** specification.

4.9.3.2. User IDs

User IDs can be defined in the container image or in the **Pod** definition.



NOTE

It is generally preferable to use supplemental group IDs to gain access to persistent storage versus using user IDs.

In the example target NFS directory shown above, the container needs its UID set to **65534**, ignoring group IDs for the moment, so the following can be added to the **Pod** definition:

```
spec:
  containers: 1
  - name:
  ...
    securityContext:
      runAsUser: 65534 2
```

1 Pods contain a **securityContext** definition specific to each container and a pod's **securityContext** which applies to all containers defined in the pod.

2 **65534** is the **nfsnobody** user.

Assuming that the project is **default** and the SCC is **restricted**, the user ID of **65534** as requested by the pod is not allowed. Therefore, the pod fails for the following reasons:

- It requests **65534** as its user ID.
- All SCCs available to the pod are examined to see which SCC allows a user ID of **65534**. While all policies of the SCCs are checked, the focus here is on user ID.
- Because all available SCCs use **MustRunAsRange** for their **runAsUser** strategy, UID range checking is required.
- **65534** is not included in the SCC or project's user ID range.

It is generally considered a good practice not to modify the predefined SCCs. The preferred way to fix this situation is to create a custom SCC A custom SCC can be created such that minimum and maximum user IDs are defined, UID range checking is still enforced, and the UID of **65534** is allowed.

NOTE

To use a custom SCC, you must first add it to the appropriate service account. For example, use the **default** service account in the given project unless another has been specified on the **Pod** specification.

4.9.3.3. SELinux

Red Hat Enterprise Linux (RHEL) and Red Hat Enterprise Linux CoreOS (RHCOS) systems are configured to use SELinux on remote NFS servers by default.

For non-RHEL and non-RHCOS systems, SELinux does not allow writing from a pod to a remote NFS server. The NFS volume mounts correctly but it is read-only. You will need to enable the correct SELinux permissions by using the following procedure.

Prerequisites

- The **container-selinux** package must be installed. This package provides the **virt_use_nfs** SELinux boolean.

Procedure

- Enable the **virt_use_nfs** boolean using the following command. The **-P** option makes this boolean persistent across reboots.

```
# setsebool -P virt_use_nfs 1
```

4.9.3.4. Export settings

To enable arbitrary container users to read and write the volume, each exported volume on the NFS server should conform to the following conditions:

- Every export must be exported using the following format:

```
/<example_fs> *(rw,root_squash)
```

- The firewall must be configured to allow traffic to the mount point.
  - For NFSv4, configure the default port **2049** (**nfs**).

    NFSv4

    ```
    # iptables -I INPUT 1 -p tcp --dport 2049 -j ACCEPT
    ```

  - For NFSv3, there are three ports to configure: **2049** (**nfs**), **20048** (**mountd**), and **111** (**portmapper**).

    NFSv3

    ```
    # iptables -I INPUT 1 -p tcp --dport 2049 -j ACCEPT
    ```

    ```
    # iptables -I INPUT 1 -p tcp --dport 20048 -j ACCEPT
    ```

    ```
    # iptables -I INPUT 1 -p tcp --dport 111 -j ACCEPT
    ```

- The NFS export and directory must be set up so that they are accessible by the target pods. Either set the export to be owned by the container's primary UID, or supply the pod group access using **supplementalGroups**, as shown in the group IDs above.

4.9.4. Reclaiming resources

NFS implements the OpenShift Container Platform **Recyclable** plugin interface. Automatic processes handle reclamation tasks based on policies set on each persistent volume.

By default, PVs are set to **Retain**.

Once claim to a PVC is deleted, and the PV is released, the PV object should not be reused. Instead, a new PV should be created with the same basic volume details as the original.

For example, the administrator creates a PV named **nfs1**:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: nfs1
spec:
  capacity:
    storage: 1Mi
  accessModes:
    - ReadWriteMany
  nfs:
    server: 192.168.1.1
    path: "/"
```

The user creates **PVC1**, which binds to **nfs1**. The user then deletes **PVC1**, releasing claim to **nfs1**. This results in **nfs1** being **Released**. If the administrator wants to make the same NFS share available, they should create a new PV with the same NFS server details, but a different PV name:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: nfs2
spec:
  capacity:
    storage: 1Mi
  accessModes:
    - ReadWriteMany
  nfs:
    server: 192.168.1.1
    path: "/"
```

Deleting the original PV and re-creating it with the same name is discouraged. Attempting to manually change the status of a PV from **Released** to **Available** causes errors and potential data loss.

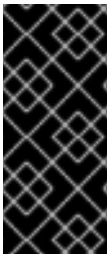
4.9.5. Additional configuration and troubleshooting

Depending on what version of NFS is being used and how it is configured, there may be additional configuration steps needed for proper export and security mapping. The following are some that may apply:

NFSv4 mount incorrectly shows all files with ownership of **nobody:nobody**	• Could be attributed to the ID mapping settings, found in **/etc/idmapd.conf** on your NFS. • See this Red Hat Solution.
Disabling ID mapping on NFSv4	• On both the NFS client and server, run: `# echo 'Y' > /sys/module/nfsd/parameters/nfs4_disable_idmapping`

4.10. RED HAT OPENSHIFT DATA FOUNDATION

Red Hat OpenShift Data Foundation is a provider of agnostic persistent storage for OpenShift Container Platform supporting file, block, and object storage, either in-house or in hybrid clouds. As a Red Hat storage solution, Red Hat OpenShift Data Foundation is completely integrated with OpenShift Container Platform for deployment, management, and monitoring. For more information, see the Red Hat OpenShift Data Foundation documentation.



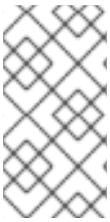
IMPORTANT

OpenShift Data Foundation on top of Red Hat Hyperconverged Infrastructure (RHHI) for Virtualization, which uses hyperconverged nodes that host virtual machines installed with OpenShift Container Platform, is not a supported configuration. For more information about supported platforms, see the Red Hat OpenShift Data Foundation Supportability and Interoperability Guide.

4.11. PERSISTENT STORAGE USING VMWARE VSPHERE VOLUMES

OpenShift Container Platform allows use of VMware vSphere's Virtual Machine Disk (VMDK) volumes. You can provision your OpenShift Container Platform cluster with persistent storage using VMware vSphere. Some familiarity with Kubernetes and VMware vSphere is assumed.

VMware vSphere volumes can be provisioned dynamically. OpenShift Container Platform creates the disk in vSphere and attaches this disk to the correct image.

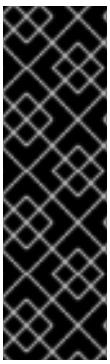


NOTE

OpenShift Container Platform provisions new volumes as independent persistent disks that can freely attach and detach the volume on any node in the cluster. Consequently, you cannot back up volumes that use snapshots, or restore volumes from snapshots. See Snapshot Limitations for more information.

The Kubernetes persistent volume framework allows administrators to provision a cluster with persistent storage and gives users a way to request those resources without having any knowledge of the underlying infrastructure.

Persistent volumes are not bound to a single project or namespace; they can be shared across the OpenShift Container Platform cluster. Persistent volume claims are specific to a project or namespace and can be requested by users.



IMPORTANT

For new installations, OpenShift Container Platform 4.13 and later provides automatic migration for the vSphere in-tree volume plugin to its equivalent CSI driver. Updating to OpenShift Container Platform 4.15 and later also provides automatic migration. For more information about updating and migration, see CSI automatic migration .

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes.

Additional resources

- VMware vSphere

4.11.1. Dynamically provisioning VMware vSphere volumes

Dynamically provisioning VMware vSphere volumes is the recommended method.

4.11.2. Prerequisites

- An OpenShift Container Platform cluster installed on a VMware vSphere version that meets the requirements for the components that you use. See Installing a cluster on vSphere for information about vSphere version support.

You can use either of the following procedures to dynamically provision these volumes using the default storage class.

4.11.2.1. Dynamically provisioning VMware vSphere volumes using the UI

OpenShift Container Platform installs a default storage class, named **thin**, that uses the **thin** disk format for provisioning volumes.

Prerequisites

- Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Procedure

1. In the OpenShift Container Platform console, click **Storage → Persistent Volume Claims**
2. In the persistent volume claims overview, click **Create Persistent Volume Claim**
3. Define the required options on the resulting page.
    a. Select the **thin** storage class.
    b. Enter a unique name for the storage claim.
    c. Select the access mode to determine the read and write access for the created storage claim.
    d. Define the size of the storage claim.
4. Click **Create** to create the persistent volume claim and generate a persistent volume.

4.11.2.2. Dynamically provisioning VMware vSphere volumes using the CLI

OpenShift Container Platform installs a default StorageClass, named **thin**, that uses the **thin** disk format for provisioning volumes.

Prerequisites

- Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Procedure (CLI)

1. You can define a VMware vSphere PersistentVolumeClaim by creating a file, **pvc.yaml**, with the following contents:

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: pvc 1
spec:
  accessModes:
  - ReadWriteOnce 2
  resources:
    requests:
      storage: 1Gi 3
```

1. A unique name that represents the persistent volume claim.
2. The access mode of the persistent volume claim. With **ReadWriteOnce**, the volume can be mounted with read and write permissions by a single node.
3. The size of the persistent volume claim.

2. Enter the following command to create the **PersistentVolumeClaim** object from the file:

```
$ oc create -f pvc.yaml
```

4.11.3. Statically provisioning VMware vSphere volumes

To statically provision VMware vSphere volumes you must create the virtual machine disks for reference by the persistent volume framework.

Prerequisites

- Storage must exist in the underlying infrastructure before it can be mounted as a volume in OpenShift Container Platform.

Procedure

1. Create the virtual machine disks. Virtual machine disks (VMDKs) must be created manually before statically provisioning VMware vSphere volumes. Use either of the following methods:
   - Create using **vmkfstools**. Access ESX through Secure Shell (SSH) and then use following command to create a VMDK volume:

```
$ vmkfstools -c <size> /vmfs/volumes/<datastore-name>/volumes/<disk-name>.vmdk
```

   - Create using **vmware-diskmanager**:

```
$ shell vmware-vdiskmanager -c -t 0 -s <size> -a lsilogic <disk-name>.vmdk
```

2. Create a persistent volume that references the VMDKs. Create a file, **pv1.yaml**, with the **PersistentVolume** object definition:

```
apiVersion: v1
```

```
kind: PersistentVolume
metadata:
  name: pv1 (1)
spec:
  capacity:
    storage: 1Gi (2)
  accessModes:
    - ReadWriteOnce
  persistentVolumeReclaimPolicy: Retain
  vsphereVolume: (3)
    volumePath: "[datastore1] volumes/myDisk" (4)
    fsType: ext4 (5)
```

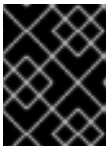
(1) The name of the volume. This name is how it is identified by persistent volume claims or pods.

(2) The amount of storage allocated to this volume.

(3) The volume type used, with **vsphereVolume** for vSphere volumes. The label is used to mount a vSphere VMDK volume into pods. The contents of a volume are preserved when it is unmounted. The volume type supports VMFS and VSAN datastore.

(4) The existing VMDK volume to use. If you used **vmkfstools**, you must enclose the datastore name in square brackets, **[]**, in the volume definition, as shown previously.

(5) The file system type to mount. For example, ext4, xfs, or other file systems.



IMPORTANT

Changing the value of the fsType parameter after the volume is formatted and provisioned can result in data loss and pod failure.

3. Create the **PersistentVolume** object from the file:

```
$ oc create -f pv1.yaml
```

4. Create a persistent volume claim that maps to the persistent volume you created in the previous step. Create a file, **pvc1.yaml**, with the **PersistentVolumeClaim** object definition:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1 (1)
spec:
  accessModes:
    - ReadWriteOnce (2)
  resources:
   requests:
     storage: "1Gi" (3)
  volumeName: pv1 (4)
```

(1) A unique name that represents the persistent volume claim.

2 The access mode of the persistent volume claim. With ReadWriteOnce, the volume can be mounted with read and write permissions by a single node.

3 The size of the persistent volume claim.

4 The name of the existing persistent volume.

5. Create the **PersistentVolumeClaim** object from the file:

```
$ oc create -f pvc1.yaml
```

4.11.3.1. Formatting VMware vSphere volumes

Before OpenShift Container Platform mounts the volume and passes it to a container, it checks that the volume contains a file system that is specified by the **fsType** parameter value in the **PersistentVolume** (PV) definition. If the device is not formatted with the file system, all data from the device is erased, and the device is automatically formatted with the specified file system.

Because OpenShift Container Platform formats them before the first use, you can use unformatted vSphere volumes as PVs.

4.12. PERSISTENT STORAGE USING LOCAL STORAGE

4.12.1. Local storage overview

You can use any of the following solutions to provision local storage:

- HostPath Provisioner (HPP)
- Local Storage Operator (LSO)
- Logical Volume Manager (LVM) Storage

WARNING

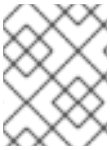
These solutions support provisioning only node-local storage. The workloads are bound to the nodes that provide the storage. If the node becomes unavailable, the workload also becomes unavailable. To maintain workload availability despite node failures, you must ensure storage data replication through active or passive replication mechanisms.

4.12.1.1. Overview of HostPath Provisioner functionality

You can perform the following actions using HostPath Provisioner (HPP):

- Map the host filesystem paths to storage classes for provisioning local storage.
- Statically create storage classes to configure filesystem paths on a node for storage consumption.

- Statically provision Persistent Volumes (PVs) based on the storage class.
- Create workloads and PersistentVolumeClaims (PVCs) while being aware of the underlying storage topology.



NOTE

HPP is available in upstream Kubernetes. However, it is not recommended to use HPP from upstream Kubernetes.

4.12.1.2. Overview of Local Storage Operator functionality

You can perform the following actions using Local Storage Operator (LSO):

- Assign the storage devices (disks or partitions) to the storage classes without modifying the device configuration.
- Statically provision PVs and storage classes by configuring the **LocalVolume** custom resource (CR).
- Create workloads and PVCs while being aware of the underlying storage topology.

NOTE

LSO is developed and delivered by Red Hat.

4.12.1.3. Overview of LVM Storage functionality

You can perform the following actions using Logical Volume Manager (LVM) Storage:

- Configure storage devices (disks or partitions) as lvm2 volume groups and expose the volume groups as storage classes.
- Create workloads and request storage by using PVCs without considering the node topology.

LVM Storage uses the TopoLVM CSI driver to dynamically allocate storage space to the nodes in the topology and provision PVs.

NOTE

LVM Storage is developed and maintained by Red Hat. The CSI driver provided with LVM Storage is the upstream project "topolvm".

4.12.1.4. Comparison of LVM Storage, LSO, and HPP

The following sections compare the functionalities provided by LVM Storage, Local Storage Operator (LSO), and HostPath Provisioner (HPP) to provision local storage.

4.12.1.4.1. Comparison of the support for storage types and filesystems

The following table compares the support for storage types and filesystems provided by LVM Storage, Local Storage Operator (LSO), and HostPath Provisioner (HPP) to provision local storage:

Table 4.1. Comparison of the support for storage types and filesystems

Functionality	LVM Storage	LSO	HPP
Support for block storage	Yes	Yes	No
Support for file storage	Yes	Yes	Yes
Support for object storage [1]	No	No	No
Available filesystems	**ext4**, **xfs**	**ext4**, **xfs**	Any mounted system available on the node is supported.

1. None of the solutions (LVM Storage, LSO, and HPP) provide support for object storage. Therefore, if you want to use object storage, you need an S3 object storage solution, such as **MultiClusterGateway** from the Red Hat OpenShift Data Foundation. All of the solutions can serve as underlying storage providers for the S3 object storage solutions.

4.12.1.4.2. Comparison of the support for core functionalities

The following table compares how LVM Storage, Local Storage Operator (LSO), and HostPath Provisioner (HPP) support core functionalities for provisioning local storage:

Table 4.2. Comparison of the support for core functionalities

Functionality	LVM Storage	LSO	HPP
Support for automatic file system formatting	Yes	Yes	N/A
Support for dynamic provisioning	Yes	No	No
Support for using software Redundant Array of Independent Disks (RAID) arrays	Yes Supported on 4.15 and later.	Yes	Yes
Support for transparent disk encryption	Yes Supported on 4.16 and later.	Yes	Yes
Support for volume based disk encryption	No	No	No
Support for disconnected installation	Yes	Yes	Yes
Support for PVC expansion	Yes	No	No

Functionality	LVM Storage	LSO	HPP
Support for volume snapshots and volume clones	Yes	No	No
Support for thin provisioning	Yes Devices are thin-provisioned by default.	Yes You can configure the devices to point to the thin-provisioned volumes	Yes You can configure a path to point to the thin-provisioned volumes.
Support for automatic disk discovery and setup	Yes Automatic disk discovery is available during installation and runtime. You can also dynamically add the disks to the **LVMCluster** custom resource (CR) to increase the storage capacity of the existing storage classes.	Technology Preview Automatic disk discovery is available during installation.	No

4.12.1.4.3. Comparison of performance and isolation capabilities

The following table compares the performance and isolation capabilities of LVM Storage, Local Storage Operator (LSO), and HostPath Provisioner (HPP) in provisioning local storage.

Table 4.3. Comparison of performance and isolation capabilities

Functionality	LVM Storage	LSO	HPP
Performance	I/O speed is shared for all workloads that use the same storage class. Block storage allows direct I/O operations. Thin provisioning can affect the performance.	I/O depends on the LSO configuration. Block storage allows direct I/O operations.	I/O speed is shared for all workloads that use the same storage class. The restrictions imposed by the underlying filesystem can affect the I/O speed.
Isolation boundary [1]	LVM Logical Volume (LV) It provides higher level of isolation compared to HPP.	LVM Logical Volume (LV) It provides higher level of isolation compared to HPP	Filesystem path It provides lower level of isolation compared to LSO and LVM Storage.

1. Isolation boundary refers to the level of separation between different workloads or applications that use local storage resources.

4.12.1.4.4. Comparison of the support for additional functionalities

The following table compares the additional features provided by LVM Storage, Local Storage Operator (LSO), and HostPath Provisioner (HPP) to provision local storage:

Table 4.4. Comparison of the support for additional functionalities

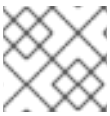
Functionality	LVM Storage	LSO	HPP
Support for generic ephemeral volumes	Yes	No	No
Support for CSI inline ephemeral volumes	No	No	No
Support for storage topology	Yes Supports CSI node topology	Yes LSO provides partial support for storage topology through node tolerations.	No
Support for **ReadWriteMany** (RWX) access mode [1]	No	No	No

1. All of the solutions (LVM Storage, LSO, and HPP) have the **ReadWriteOnce** (RWO) access mode. RWO access mode allows access from multiple pods on the same node.

4.12.2. Persistent storage using local volumes

OpenShift Container Platform can be provisioned with persistent storage by using local volumes. Local persistent volumes allow you to access local storage devices, such as a disk or partition, by using the standard persistent volume claim interface.

Local volumes can be used without manually scheduling pods to nodes because the system is aware of the volume node constraints. However, local volumes are still subject to the availability of the underlying node and are not suitable for all applications.



NOTE

Local volumes can only be used as a statically created persistent volume.

4.12.2.1. Installing the Local Storage Operator

The Local Storage Operator is not installed in OpenShift Container Platform by default. Use the following procedure to install and configure this Operator to enable local volumes in your cluster.

Prerequisites

- Access to the OpenShift Container Platform web console or command-line interface (CLI).

Procedure

1. Create the **openshift-local-storage** project:

```
$ oc adm new-project openshift-local-storage
```

2. Optional: Allow local storage creation on infrastructure nodes.
You might want to use the Local Storage Operator to create volumes on infrastructure nodes in support of components such as logging and monitoring.

   You must adjust the default node selector so that the Local Storage Operator includes the infrastructure nodes, and not just worker nodes.

   To block the Local Storage Operator from inheriting the cluster-wide default selector, enter the following command:

```
$ oc annotate namespace openshift-local-storage openshift.io/node-selector=''
```

3. Optional: Allow local storage to run on the management pool of CPUs in single-node deployment.
Use the Local Storage Operator in single-node deployments and allow the use of CPUs that belong to the **management** pool. Perform this step on single-node installations that use management workload partitioning.

   To allow Local Storage Operator to run on the management CPU pool, run following commands:

```
$ oc annotate namespace openshift-local-storage
workload.openshift.io/allowed='management'
```

From the UI

To install the Local Storage Operator from the web console, follow these steps:

1. Log in to the OpenShift Container Platform web console.
2. Navigate to **Operators → OperatorHub**.
3. Type **Local Storage** into the filter box to locate the Local Storage Operator.
4. Click **Install**.
5. On the **Install Operator** page, select **A specific namespace on the cluster**. Select **openshift-local-storage** from the drop-down menu.
6. Adjust the values for **Update Channel** and **Approval Strategy** to the values that you want.
7. Click **Install**.

Once finished, the Local Storage Operator will be listed in the **Installed Operators** section of the web console.

From the CLI

1. Install the Local Storage Operator from the CLI.

   a. Create an object YAML file to define an Operator group and subscription for the Local Storage Operator, such as **openshift-local-storage.yaml**:

   Example openshift-local-storage.yaml

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: local-operator-group
  namespace: openshift-local-storage
spec:
  targetNamespaces:
    - openshift-local-storage
---
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: local-storage-operator
  namespace: openshift-local-storage
spec:
  channel: stable
  installPlanApproval: Automatic (1)
  name: local-storage-operator
  source: redhat-operators
  sourceNamespace: openshift-marketplace
```

   (1) The user approval policy for an install plan.

2. Create the Local Storage Operator object by entering the following command:

```
$ oc apply -f openshift-local-storage.yaml
```

   At this point, the Operator Lifecycle Manager (OLM) is now aware of the Local Storage Operator. A ClusterServiceVersion (CSV) for the Operator should appear in the target namespace, and APIs provided by the Operator should be available for creation.

3. Verify local storage installation by checking that all pods and the Local Storage Operator have been created:

   a. Check that all the required pods have been created:

```
$ oc -n openshift-local-storage get pods
```

   Example output

```
NAME                                      READY   STATUS    RESTARTS   AGE
local-storage-operator-746bf599c9-vlt5t   1/1     Running   0          19m
```

   b. Check the ClusterServiceVersion (CSV) YAML manifest to see that the Local Storage Operator is available in the **openshift-local-storage** project:

```
$ oc get csvs -n openshift-local-storage
```

Example output

```
NAME                                         DISPLAY         VERSION               REPLACES   PHASE
local-storage-operator.4.2.26-202003230335   Local Storage   4.2.26-202003230335              Succeeded
```

After all checks have passed, the Local Storage Operator is installed successfully.

4.12.2.2. Provisioning local volumes by using the Local Storage Operator

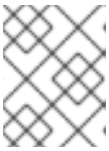
Local volumes cannot be created by dynamic provisioning. Instead, persistent volumes can be created by the Local Storage Operator. The local volume provisioner looks for any file system or block volume devices at the paths specified in the defined resource.

Prerequisites

- The Local Storage Operator is installed.
- You have a local disk that meets the following conditions:
  - It is attached to a node.
  - It is not mounted.
  - It does not contain partitions.

Procedure

1. Create the local volume resource. This resource must define the nodes and paths to the local volumes.



NOTE

Do not use different storage class names for the same device. Doing so will create multiple persistent volumes (PVs).

Example: Filesystem

```
apiVersion: "local.storage.openshift.io/v1"
kind: "LocalVolume"
metadata:
  name: "local-disks"
  namespace: "openshift-local-storage" (1)
spec:
  nodeSelector: (2)
    nodeSelectorTerms:
    - matchExpressions:
        - key: kubernetes.io/hostname
          operator: In
          values:
          - ip-10-0-140-183
          - ip-10-0-158-139
          - ip-10-0-164-33
```

```
storageClassDevices:
  - storageClassName: "local-sc" 3
    forceWipeDevicesAndDestroyAllData: false 4
    volumeMode: Filesystem 5
    fsType: xfs 6
    devicePaths: 7
      - /path/to/device 8
```

1. The namespace where the Local Storage Operator is installed.

2. Optional: A node selector containing a list of nodes where the local storage volumes are attached. This example uses the node hostnames, obtained from **oc get node**. If a value is not defined, then the Local Storage Operator will attempt to find matching disks on all available nodes.

3. The name of the storage class to use when creating persistent volume objects. The Local Storage Operator automatically creates the storage class if it does not exist. Be sure to use a storage class that uniquely identifies this set of local volumes.

4. This setting defines whether or not to call **wipefs**, which removes partition table signatures (magic strings) making the disk ready to use for Local Storage Operator (LSO) provisioning. No other data besides signatures is erased. The default is "false" (**wipefs** is not invoked). Setting **forceWipeDevicesAndDestroyAllData** to "true" can be useful in scenarios where previous data can remain on disks that need to be re-used. In these scenarios, setting this field to true eliminates the need for administrators to erase the disks manually. Such cases can include single-node OpenShift (SNO) cluster environments where a node can be redeployed multiple times or when using OpenShift Data Foundation (ODF), where previous data can remain on the disks planned to be consumed as object storage devices (OSDs).

5. The volume mode, either **Filesystem** or **Block**, that defines the type of local volumes.

NOTE

A raw block volume (**volumeMode: Block**) is not formatted with a file system. Use this mode only if any application running on the pod can use raw block devices.

6. The file system that is created when the local volume is mounted for the first time.

7. The path containing a list of local storage devices to choose from.

8. Replace this value with your actual local disks filepath to the **LocalVolume** resource **by-id**, such as **/dev/disk/by-id/wwn**. PVs are created for these local disks when the provisioner is deployed successfully.

NOTE

If you are running OpenShift Container Platform with RHEL KVM, you must assign a serial number to your VM disk. Otherwise, the VM disk can not be identified after reboot. You can use the **virsh edit <VM>** command to add the **<serial>mydisk</serial>** definition.

Example: Block

```
apiVersion: "local.storage.openshift.io/v1"
kind: "LocalVolume"
metadata:
  name: "local-disks"
  namespace: "openshift-local-storage" (1)
spec:
  nodeSelector: (2)
    nodeSelectorTerms:
    - matchExpressions:
        - key: kubernetes.io/hostname
          operator: In
          values:
          - ip-10-0-136-143
          - ip-10-0-140-255
          - ip-10-0-144-180
  storageClassDevices:
    - storageClassName: "local-sc" (3)
      forceWipeDevicesAndDestroyAllData: false (4)
      volumeMode: Block (5)
      devicePaths: (6)
        - /path/to/device (7)
```

(1) The namespace where the Local Storage Operator is installed.

(2) Optional: A node selector containing a list of nodes where the local storage volumes are attached. This example uses the node hostnames, obtained from **oc get node**. If a value is not defined, then the Local Storage Operator will attempt to find matching disks on all available nodes.

(3) The name of the storage class to use when creating persistent volume objects.

(4) This setting defines whether or not to call **wipefs**, which removes partition table signatures (magic strings) making the disk ready to use for Local Storage Operator (LSO) provisioning. No other data besides signatures is erased. The default is "false" (**wipefs** is not invoked). Setting **forceWipeDevicesAndDestroyAllData** to "true" can be useful in scenarios where previous data can remain on disks that need to be re-used. In these scenarios, setting this field to true eliminates the need for administrators to erase the disks manually. Such cases can include single-node OpenShift (SNO) cluster environments where a node can be redeployed multiple times or when using OpenShift Data Foundation (ODF), where previous data can remain on the disks planned to be consumed as object storage devices (OSDs).

(5) The volume mode, either **Filesystem** or **Block**, that defines the type of local volumes.

(6) The path containing a list of local storage devices to choose from.

(7) Replace this value with your actual local disks filepath to the **LocalVolume** resource **by-id**, such as **dev/disk/by-id/wwn**. PVs are created for these local disks when the provisioner is deployed successfully.

NOTE

If you are running OpenShift Container Platform with RHEL KVM, you must assign a serial number to your VM disk. Otherwise, the VM disk can not be identified after reboot. You can use the **virsh edit <VM>** command to add the **<serial>mydisk</serial>** definition.

2. Create the local volume resource in your OpenShift Container Platform cluster. Specify the file you just created:

```
$ oc create -f <local-volume>.yaml
```

3. Verify that the provisioner was created and that the corresponding daemon sets were created:

```
$ oc get all -n openshift-local-storage
```

Example output

```
NAME                                      READY   STATUS    RESTARTS   AGE
pod/diskmaker-manager-9wzms               1/1     Running   0          5m43s
pod/diskmaker-manager-jgvjp               1/1     Running   0          5m43s
pod/diskmaker-manager-tbdsj               1/1     Running   0          5m43s
pod/local-storage-operator-7db4bd9f79-t6k87   1/1     Running   0          14m

NAME                                  TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)
AGE
service/local-storage-operator-metrics   ClusterIP   172.30.135.36   <none>
8383/TCP,8686/TCP   14m

NAME                         DESIRED   CURRENT   READY   UP-TO-DATE   AVAILABLE
NODE SELECTOR   AGE
daemonset.apps/diskmaker-manager   3         3         3       3            3           <none>
5m43s

NAME                                 READY   UP-TO-DATE   AVAILABLE   AGE
deployment.apps/local-storage-operator   1/1     1            1           14m

NAME                                            DESIRED   CURRENT   READY   AGE
replicaset.apps/local-storage-operator-7db4bd9f79   1         1         1       14m
```

Note the desired and current number of daemon set processes. A desired count of **0** indicates that the label selectors were invalid.

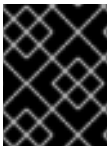
4. Verify that the persistent volumes were created:

```
$ oc get pv
```

Example output

```
NAME                CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS      CLAIM
STORAGECLASS    REASON   AGE
local-pv-1cec77cf   100Gi      RWO            Delete           Available           local-sc                88m
```

```
local-pv-2ef7cd2a   100Gi   RWO   Delete   Available   local-sc
82m
local-pv-3fa1c73    100Gi   RWO   Delete   Available   local-sc   48m
```



IMPORTANT

Editing the **LocalVolume** object does not change the **fsType** or **volumeMode** of existing persistent volumes because doing so might result in a destructive operation.

4.12.2.3. Provisioning local volumes without the Local Storage Operator

Local volumes cannot be created by dynamic provisioning. Instead, persistent volumes can be created by defining the persistent volume (PV) in an object definition. The local volume provisioner looks for any file system or block volume devices at the paths specified in the defined resource.

IMPORTANT

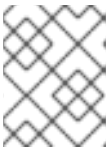
Manual provisioning of PVs includes the risk of potential data leaks across PV reuse when PVCs are deleted. The Local Storage Operator is recommended for automating the life cycle of devices when provisioning local PVs.

Prerequisites

- Local disks are attached to the OpenShift Container Platform nodes.

Procedure

1. Define the PV. Create a file, such as **example-pv-filesystem.yaml** or **example-pv-block.yaml**, with the **PersistentVolume** object definition. This resource must define the nodes and paths to the local volumes.



NOTE

Do not use different storage class names for the same device. Doing so will create multiple PVs.

example-pv-filesystem.yaml

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: example-pv-filesystem
spec:
  capacity:
    storage: 100Gi
  volumeMode: Filesystem (1)
  accessModes:
  - ReadWriteOnce
  persistentVolumeReclaimPolicy: Delete
  storageClassName: local-sc (2)
  local:
    path: /dev/xvdf (3)
  nodeAffinity:
```

```
  required:
    nodeSelectorTerms:
    - matchExpressions:
      - key: kubernetes.io/hostname
        operator: In
        values:
        - example-node
```

1. The volume mode, either **Filesystem** or **Block**, that defines the type of PVs.
2. The name of the storage class to use when creating PV resources. Use a storage class that uniquely identifies this set of PVs.
3. The path containing a list of local storage devices to choose from, or a directory. You can only specify a directory with **Filesystem volumeMode**.

NOTE

A raw block volume (**volumeMode: block**) is not formatted with a file system. Use this mode only if any application running on the pod can use raw block devices.

example-pv-block.yaml

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: example-pv-block
spec:
  capacity:
    storage: 100Gi
  volumeMode: Block (1)
  accessModes:
  - ReadWriteOnce
  persistentVolumeReclaimPolicy: Delete
  storageClassName: local-sc (2)
  local:
    path: /dev/xvdf (3)
  nodeAffinity:
    required:
      nodeSelectorTerms:
      - matchExpressions:
        - key: kubernetes.io/hostname
          operator: In
          values:
          - example-node
```

1. The volume mode, either **Filesystem** or **Block**, that defines the type of PVs.
2. The name of the storage class to use when creating PV resources. Be sure to use a storage class that uniquely identifies this set of PVs.
3. The path containing a list of local storage devices to choose from.

2. Create the PV resource in your OpenShift Container Platform cluster. Specify the file you just created:

```
$ oc create -f <example-pv>.yaml
```

3. Verify that the local PV was created:

```
$ oc get pv
```

Example output

```
NAME                CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS      CLAIM
STORAGECLASS   REASON   AGE
example-pv-filesystem   100Gi      RWO            Delete           Available                   local-sc
3m47s
example-pv1         1Gi        RWO            Delete           Bound       local-storage/pvc1   local-
sc             12h
example-pv2         1Gi        RWO            Delete           Bound       local-storage/pvc2   local-
sc             12h
example-pv3         1Gi        RWO            Delete           Bound       local-storage/pvc3   local-
sc             12h
```

4.12.2.4. Creating the local volume persistent volume claim

Local volumes must be statically created as a persistent volume claim (PVC) to be accessed by the pod.

Prerequisites

- Persistent volumes have been created using the local volume provisioner.

Procedure

1. Create the PVC using the corresponding storage class:

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: local-pvc-name 1
spec:
  accessModes:
  - ReadWriteOnce
  volumeMode: Filesystem 2
  resources:
    requests:
      storage: 100Gi 3
  storageClassName: local-sc 4
```

1. Name of the PVC.
2. The type of the PVC. Defaults to **Filesystem**.
3. The amount of storage available to the PVC.

4 Name of the storage class required by the claim.

2. Create the PVC in the OpenShift Container Platform cluster, specifying the file you just created:

```
$ oc create -f <local-pvc>.yaml
```

4.12.2.5. Attach the local claim

After a local volume has been mapped to a persistent volume claim it can be specified inside of a resource.

Prerequisites

- A persistent volume claim exists in the same namespace.

Procedure

1. Include the defined claim in the resource spec. The following example declares the persistent volume claim inside a pod:

```
apiVersion: v1
kind: Pod
spec:
# ...
  containers:
    volumeMounts:
    - name: local-disks 1
      mountPath: /data 2
  volumes:
  - name: local-disks
    persistentVolumeClaim:
      claimName: local-pvc-name 3
# ...
```

1 The name of the volume to mount.

2 The path inside the pod where the volume is mounted. Do not mount to the container root, /, or any path that is the same in the host and the container. This can corrupt your host system if the container is sufficiently privileged, such as the host **/dev/pts** files. It is safe to mount the host by using **/host**.

3 The name of the existing persistent volume claim to use.

2. Create the resource in the OpenShift Container Platform cluster, specifying the file you just created:

```
$ oc create -f <local-pod>.yaml
```

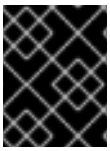
4.12.2.6. Automating discovery and provisioning for local storage devices

The Local Storage Operator automates local storage discovery and provisioning. With this feature, you can simplify installation when dynamic provisioning is not available during deployment, such as with bare metal, VMware, or AWS store instances with attached devices.

IMPORTANT

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

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



IMPORTANT

Automatic discovery and provisioning is fully supported when used to deploy Red Hat OpenShift Data Foundation on-premise or with platform-agnostic deployment.

Use the following procedure to automatically discover local devices, and to automatically provision local volumes for selected devices.

WARNING

Use the **LocalVolumeSet** object with caution. When you automatically provision persistent volumes (PVs) from local disks, the local PVs might claim all devices that match. If you are using a **LocalVolumeSet** object, make sure the Local Storage Operator is the only entity managing local devices on the node. Creating multiple instances of a **LocalVolumeSet** that target a node more than once is not supported.

Prerequisites

- You have cluster administrator permissions.
- You have installed the Local Storage Operator.
- You have attached local disks to OpenShift Container Platform nodes.
- You have access to the OpenShift Container Platform web console and the **oc** command-line interface (CLI).

Procedure

1. To enable automatic discovery of local devices from the web console:
   a. Click **Operators → Installed Operators**.
   b. In the **openshift-local-storage** namespace, click **Local Storage**.

c. Click the **Local Volume Discovery** tab.

d. Click **Create Local Volume Discovery** and then select either **Form view** or **YAML view**.

e. Configure the **LocalVolumeDiscovery** object parameters.

f. Click **Create**.
The Local Storage Operator creates a local volume discovery instance named **auto-discover-devices**.

2. To display a continuous list of available devices on a node:

a. Log in to the OpenShift Container Platform web console.

b. Navigate to **Compute → Nodes**.

c. Click the node name that you want to open. The "Node Details" page is displayed.

d. Select the **Disks** tab to display the list of the selected devices.
The device list updates continuously as local disks are added or removed. You can filter the devices by name, status, type, model, capacity, and mode.

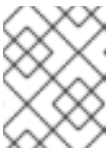
3. To automatically provision local volumes for the discovered devices from the web console:

a. Navigate to **Operators → Installed Operators** and select **Local Storage** from the list of Operators.

b. Select **Local Volume Set → Create Local Volume Set**

c. Enter a volume set name and a storage class name.

d. Choose **All nodes** or **Select nodes** to apply filters accordingly.



NOTE

Only worker nodes are available, regardless of whether you filter using **All nodes** or **Select nodes**.

e. Select the disk type, mode, size, and limit you want to apply to the local volume set, and click **Create**.
A message displays after several minutes, indicating that the "Operator reconciled successfully."

4. Alternatively, to provision local volumes for the discovered devices from the CLI:

a. Create an object YAML file to define the local volume set, such as **local-volume-set.yaml**, as shown in the following example:

```
apiVersion: local.storage.openshift.io/v1alpha1
kind: LocalVolumeSet
metadata:
  name: example-autodetect
spec:
  nodeSelector:
    nodeSelectorTerms:
      - matchExpressions:
```

```
        - key: kubernetes.io/hostname
          operator: In
          values:
            - worker-0
            - worker-1
  storageClassName: local-sc (1)
  volumeMode: Filesystem
  fsType: ext4
  maxDeviceCount: 10
  deviceInclusionSpec:
   deviceTypes: (2)
     - disk
     - part
   deviceMechanicalProperties:
     - NonRotational
   minSize: 10G
   maxSize: 100G
   models:
     - SAMSUNG
     - Crucial_CT525MX3
   vendors:
     - ATA
     - ST2000LM
```

(1) Determines the storage class that is created for persistent volumes that are provisioned from discovered devices. The Local Storage Operator automatically creates the storage class if it does not exist. Be sure to use a storage class that uniquely identifies this set of local volumes.

(2) When using the local volume set feature, the Local Storage Operator does not support the use of logical volume management (LVM) devices.

b. Create the local volume set object:

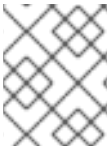
```
$ oc apply -f local-volume-set.yaml
```

c. Verify that the local persistent volumes were dynamically provisioned based on the storage class:

```
$ oc get pv
```

Example output

```
NAME                CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS
CLAIM   STORAGECLASS   REASON   AGE
local-pv-1cec77cf   100Gi      RWO            Delete           Available
local-sc                88m
local-pv-2ef7cd2a   100Gi      RWO            Delete           Available
local-sc                82m
local-pv-3fa1c73    100Gi      RWO            Delete           Available
local-sc                48m
```



NOTE

Results are deleted after they are removed from the node. Symlinks must be manually removed.

4.12.2.7. Using tolerations with Local Storage Operator pods

Taints can be applied to nodes to prevent them from running general workloads. To allow the Local Storage Operator to use tainted nodes, you must add tolerations to the **Pod** or **DaemonSet** definition. This allows the created resources to run on these tainted nodes.

You apply tolerations to the Local Storage Operator pod through the **LocalVolume** resource and apply taints to a node through the node specification. A taint on a node instructs the node to repel all pods that do not tolerate the taint. Using a specific taint that is not on other pods ensures that the Local Storage Operator pod can also run on that node.

IMPORTANT

Taints and tolerations consist of a key, value, and effect. As an argument, it is expressed as **key=value:effect**. An operator allows you to leave one of these parameters empty.

Prerequisites

- The Local Storage Operator is installed.
- Local disks are attached to OpenShift Container Platform nodes with a taint.
- Tainted nodes are expected to provision local storage.

Procedure

To configure local volumes for scheduling on tainted nodes:

1. Modify the YAML file that defines the **Pod** and add the **LocalVolume** spec, as shown in the following example:

```
apiVersion: "local.storage.openshift.io/v1"
kind: "LocalVolume"
metadata:
  name: "local-disks"
  namespace: "openshift-local-storage"
spec:
  tolerations:
    - key: localstorage 1
      operator: Equal 2
      value: "localstorage" 3
  storageClassDevices:
    - storageClassName: "local-sc"
      volumeMode: Block 4
      devicePaths: 5
        - /dev/xvdg
```

1. Specify the key that you added to the node.
2. Specify the **Equal** operator to require the **key**/**value** parameters to match. If operator is **Exists**, the system checks that the key exists and ignores the value. If operator is **Equal**

Exists, the system checks that the key exists and ignores the value. If operator is **Equal**, then the key and value must match.

3 Specify the value **local** of the tainted node.

4 The volume mode, either **Filesystem** or **Block**, defining the type of the local volumes.

5 The path containing a list of local storage devices to choose from.

2. Optional: To create local persistent volumes on only tainted nodes, modify the YAML file and add the **LocalVolume** spec, as shown in the following example:

```
spec:
  tolerations:
    - key: node-role.kubernetes.io/master
      operator: Exists
```

The defined tolerations will be passed to the resulting daemon sets, allowing the diskmaker and provisioner pods to be created for nodes that contain the specified taints.

4.12.2.8. Local Storage Operator Metrics

OpenShift Container Platform provides the following metrics for the Local Storage Operator:

- **lso_discovery_disk_count**: total number of discovered devices on each node
- **lso_lvset_provisioned_PV_count**: total number of PVs created by **LocalVolumeSet** objects
- **lso_lvset_unmatched_disk_count**: total number of disks that Local Storage Operator did not select for provisioning because of mismatching criteria
- **lso_lvset_orphaned_symlink_count**: number of devices with PVs that no longer match **LocalVolumeSet** object criteria
- **lso_lv_orphaned_symlink_count**: number of devices with PVs that no longer match **LocalVolume** object criteria
- **lso_lv_provisioned_PV_count**: total number of provisioned PVs for **LocalVolume**

To use these metrics, enable them by doing one of the following:

- When installing the Local Storage Operator from *OperatorHub* in the web console, select the *Enable Operator recommended cluster monitoring on this Namespace* checkbox.
- Manually add the **openshift.io/cluster-monitoring=true** label to the Operator namespace by running the following command:

```
$ oc label ns/openshift-local-storage openshift.io/cluster-monitoring=true
```

For more information about metrics, see Accessing metrics as an administrator .

4.12.2.9. Deleting the Local Storage Operator resources

4.12.2.9.1. Removing a local volume or local volume set

Occasionally, you need to delete local volumes (LVs) and local volume sets (LVSs).

Prerequisites

- The persistent volume (PV) must be in a **Released** or **Available** state.

WARNING

Deleting a persistent volume that is still in use can result in data loss or corruption.

Procedure

To delete LVs or LVSs, complete the following steps:

1. If there are any bound PVs owned by the LV or LVS that is being deleted, delete the corresponding persistent volume claims (PVCs) to release the PVs:

   a. To find bound PVs owned by a particular LV or LVS, run the following command:

   ```
   $ oc get pv --selector storage.openshift.com/owner-name=<LV_LVS_name>
   ```
   (1)

   (1) **<LV_LVS_name>** is the name of the LV or LVS.

   #### Example output

   ```
   NAME                CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS
   CLAIM               STORAGECLASS   VOLUMEATTRIBUTESCLASS   REASON   AGE
   local-pv-3fa1c73    5Gi        RWO            Delete           Available
   slow           <unset>                 28s
   local-pv-1cec77cf   30Gi       RWX            Retain           Bound
   openshift/storage   my-sc          <unset>                 168d
   ```

   Bound PVs have a status of **Bound** and their corresponding PVCs appear in the **CLAIM** column. In the preceding example, PV **local-pv-1cec77cf** is bound, and its PVC is **openshift/storage**.

   b. Delete corresponding PVCs of bound PVs owned by the LV or LVS being deleted by running the following command:

   ```
   $ oc delete pvc <name>
   ```

   In this example, you would delete PVC **openshift/storage**.

2. Delete the LVs or LVSs by running the applicable following command:

   #### Command for deleting LV

   ```
   $ oc delete lv <name>
   ```

or

Command for deleting LVS

```
$ oc delete lvs <name>
```

3. If any PV owned by the LV or LVS has a **Retain** reclaim policy, back up any important data, and then delete the PV:

NOTE

PVs with a **Delete** policy are automatically deleted when you delete the LVs or LVS.

a. To find PVs with **Retain** reclaim policy, run the following command:

```
$ oc get pv
```

Example output

```
NAME                CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS
CLAIM               STORAGECLASS   REASON   AGE
local-pv-1cec77cf   30Gi       RWX            Retain           Available                   my-sc
168d
```

In this example, PV **local-pv-1cec77cf** has a **Retain** reclaim policy and needs to be manually deleted.

b. Back up any important data on this volume.

c. Delete the PV by running the following command:

```
$ oc delete pv <name>
```

In this example, delete PV **local-pv-1cec77cf**.

4.12.2.9.2. Uninstalling the Local Storage Operator

To uninstall the Local Storage Operator, you must remove the Operator and all created resources in the **openshift-local-storage** project.

WARNING

Uninstalling the Local Storage Operator while local storage PVs are still in use is not recommended. While the PVs will remain after the Operator's removal, there might be indeterminate behavior if the Operator is uninstalled and reinstalled without removing the PVs and local storage resources.

Prerequisites

- Access to the OpenShift Container Platform web console.

Procedure

1. Delete any local volume resources installed in the project, such as **localvolume**, **localvolumeset**, and **localvolumediscovery** by running the following commands:

```
$ oc delete localvolume --all --all-namespaces
```

```
$ oc delete localvolumeset --all --all-namespaces
```

```
$ oc delete localvolumediscovery --all --all-namespaces
```

2. Uninstall the Local Storage Operator from the web console.
   a. Log in to the OpenShift Container Platform web console.
   b. Navigate to **Operators → Installed Operators**.
   c. Type **Local Storage** into the filter box to locate the Local Storage Operator.
   d. Click the Options menu  at the end of the Local Storage Operator.
   e. Click **Uninstall Operator**.
   f. Click **Remove** in the window that appears.
3. The PVs created by the Local Storage Operator will remain in the cluster until deleted. After these volumes are no longer in use, delete them by running the following command:

```
$ oc delete pv <pv-name>
```

4. Delete the **openshift-local-storage** project by running the following command:

```
$ oc delete project openshift-local-storage
```

4.12.3. Persistent storage using hostPath

A hostPath volume in an OpenShift Container Platform cluster mounts a file or directory from the host node's filesystem into your pod. Most pods will not need a hostPath volume, but it does offer a quick option for testing should an application require it.

IMPORTANT

The cluster administrator must configure pods to run as privileged. This grants access to pods in the same node.

4.12.3.1. Overview

OpenShift Container Platform supports hostPath mounting for development and testing on a single-node cluster.

In a production cluster, you would not use hostPath. Instead, a cluster administrator would provision a network resource, such as a GCE Persistent Disk volume, an NFS share, or an Amazon EBS volume. Network resources support the use of storage classes to set up dynamic provisioning.

A hostPath volume must be provisioned statically.

IMPORTANT

Do not mount to the container root, /, or any path that is the same in the host and the container. This can corrupt your host system if the container is sufficiently privileged. It is safe to mount the host by using **/host**. The following example shows the / directory from the host being mounted into the container at **/host**.

```
apiVersion: v1
kind: Pod
metadata:
  name: test-host-mount
spec:
  containers:
  - image: registry.access.redhat.com/ubi9/ubi
    name: test-container
    command: ['sh', '-c', 'sleep 3600']
    volumeMounts:
    - mountPath: /host
      name: host-slash
  volumes:
   - name: host-slash
     hostPath:
       path: /
       type: ''
```

4.12.3.2. Statically provisioning hostPath volumes

A pod that uses a hostPath volume must be referenced by manual (static) provisioning.

Procedure

1. Define the persistent volume (PV) by creating a **pv.yaml** file with the **PersistentVolume** object definition:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: task-pv-volume 1
  labels:
    type: local
spec:
  storageClassName: manual 2
  capacity:
    storage: 5Gi
  accessModes:
    - ReadWriteOnce 3
```

```
  persistentVolumeReclaimPolicy: Retain
  hostPath:
    path: "/mnt/data" 4
```

1. The name of the volume. This name is how the volume is identified by persistent volume (PV) claims or pods.
2. Used to bind persistent volume claim (PVC) requests to the PV.
3. The volume can be mounted as **read-write** by a single node.
4. The configuration file specifies that the volume is at **/mnt/data** on the cluster's node. To avoid corrupting your host system, do not mount to the container root, /, or any path that is the same in the host and the container. You can safely mount the host by using **/host**

2. Create the PV from the file:

```
$ oc create -f pv.yaml
```

3. Define the PVC by creating a **pvc.yaml** file with the **PersistentVolumeClaim** object definition:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: task-pvc-volume
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  storageClassName: manual
```

4. Create the PVC from the file:

```
$ oc create -f pvc.yaml
```

4.12.3.3. Mounting the hostPath share in a privileged pod

After the persistent volume claim has been created, it can be used inside by an application. The following example demonstrates mounting this share inside of a pod.

Prerequisites

- A persistent volume claim exists that is mapped to the underlying hostPath share.

Procedure

- Create a privileged pod that mounts the existing persistent volume claim:

```
apiVersion: v1
kind: Pod
metadata:
```

```
  name: pod-name 1
spec:
  containers:
    ...
    securityContext:
      privileged: true 2
    volumeMounts:
    - mountPath: /data 3
      name: hostpath-privileged
  ...
  securityContext: {}
  volumes:
    - name: hostpath-privileged
      persistentVolumeClaim:
        claimName: task-pvc-volume 4
```

1. The name of the pod.
2. The pod must run as privileged to access the node's storage.
3. The path to mount the host path share inside the privileged pod. Do not mount to the container root, /, or any path that is the same in the host and the container. This can corrupt your host system if the container is sufficiently privileged, such as the host **/dev/pts** files. It is safe to mount the host by using **/host**.
4. The name of the **PersistentVolumeClaim** object that has been previously created.

4.12.4. Persistent storage using Logical Volume Manager Storage

Logical Volume Manager (LVM) Storage uses LVM2 through the TopoLVM CSI driver to dynamically provision local storage on a cluster with limited resources.

You can create volume groups, persistent volume claims (PVCs), volume snapshots, and volume clones by using LVM Storage.

4.12.4.1. Logical Volume Manager Storage installation

You can install Logical Volume Manager (LVM) Storage on an OpenShift Container Platform cluster and configure it to dynamically provision storage for your workloads.

You can install LVM Storage by using the OpenShift Container Platform CLI (**oc**), OpenShift Container Platform web console, or Red Hat Advanced Cluster Management (RHACM).

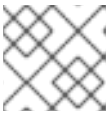
WARNING

When using LVM Storage on multi-node clusters, LVM Storage only supports provisioning local storage. LVM Storage does not support storage data replication mechanisms across nodes. You must ensure storage data replication through active or passive replication mechanisms to avoid a single point of failure.

4.12.4.1.1. Prerequisites to install LVM Storage

The prerequisites to install LVM Storage are as follows:

- Ensure that you have a minimum of 10 milliCPU and 100 MiB of RAM.
- Ensure that every managed cluster has dedicated disks that are used to provision storage. LVM Storage uses only those disks that are empty and do not contain file system signatures. To ensure that the disks are empty and do not contain file system signatures, wipe the disks before using them.
- Before installing LVM Storage in a private CI environment where you can reuse the storage devices that you configured in the previous LVM Storage installation, ensure that you have wiped the disks that are not in use. If you do not wipe the disks before installing LVM Storage, you cannot reuse the disks without manual intervention.



NOTE

You cannot wipe the disks that are in use.

- If you want to install LVM Storage by using Red Hat Advanced Cluster Management (RHACM), ensure that you have installed RHACM on an OpenShift Container Platform cluster. See the "Installing LVM Storage using RHACM" section.

Additional resources

- Red Hat Advanced Cluster Management for Kubernetes: Installing while connected online

4.12.4.1.2. Installing LVM Storage by using the CLI

As a cluster administrator, you can install LVM Storage by using the OpenShift CLI.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to OpenShift Container Platform as a user with **cluster-admin** and Operator installation permissions.

Procedure

1. Create a YAML file with the configuration for creating a namespace:

Example YAML configuration for creating a namespace

```
apiVersion: v1
kind: Namespace
metadata:
  labels:
    openshift.io/cluster-monitoring: "true"
    pod-security.kubernetes.io/enforce: privileged
    pod-security.kubernetes.io/audit: privileged
    pod-security.kubernetes.io/warn: privileged
  name: openshift-storage
```

2. Create the namespace by running the following command:

```
$ oc create -f <file_name>
```

3. Create an **OperatorGroup** CR YAML file:

Example OperatorGroup CR

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: openshift-storage-operatorgroup
  namespace: openshift-storage
spec:
  targetNamespaces:
  - openshift-storage
```

4. Create the **OperatorGroup** CR by running the following command:

```
$ oc create -f <file_name>
```

5. Create a **Subscription** CR YAML file:

Example Subscription CR

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: lvms
  namespace: openshift-storage
spec:
  installPlanApproval: Automatic
  name: lvms-operator
  source: redhat-operators
  sourceNamespace: openshift-marketplace
```

6. Create the **Subscription** CR by running the following command:

```
$ oc create -f <file_name>
```

Verification

1. To verify that LVM Storage is installed, run the following command:

```
$ oc get csv -n openshift-storage -o custom-
columns=Name:.metadata.name,Phase:.status.phase
```

Example output

```
Name                    Phase
4.13.0-202301261535     Succeeded
```

4.12.4.1.3. Installing LVM Storage by using the web console

You can install LVM Storage by using the OpenShift Container Platform web console.

Prerequisites

- You have access to the cluster.
- You have access to OpenShift Container Platform with **cluster-admin** and Operator installation permissions.

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Click **Operators → OperatorHub**.
3. Click **LVM Storage** on the **OperatorHub** page.
4. Set the following options on the **Operator Installation** page:
   a. **Update Channel** as **stable-4.18**.
   b. **Installation Mode** as **A specific namespace on the cluster**
   c. **Installed Namespace** as **Operator recommended namespace openshift-storage**. If the **openshift-storage** namespace does not exist, it is created during the operator installation.
   d. **Update approval** as **Automatic** or **Manual**.

NOTE

If you select **Automatic** updates, the Operator Lifecycle Manager (OLM) automatically updates the running instance of LVM Storage without any intervention.

If you select **Manual** updates, the OLM creates an update request. As a cluster administrator, you must manually approve the update request to update LVM Storage to a newer version.

5. Optional: Select the **Enable Operator recommended cluster monitoring on this Namespace** checkbox.
6. Click **Install**.

Verification steps

- Verify that LVM Storage shows a green tick, indicating successful installation.

4.12.4.1.4. Installing LVM Storage in a disconnected environment

You can install LVM Storage on OpenShift Container Platform in a disconnected environment. All sections referenced in this procedure are linked in the "Additional resources" section.

Prerequisites

- You read the "About disconnected installation mirroring" section.
- You have access to the OpenShift Container Platform image repository.
- You created a mirror registry.

Procedure

1. Follow the steps in the "Creating the image set configuration" procedure. To create an **ImageSetConfiguration** custom resource (CR) for LVM Storage, you can use the following example **ImageSetConfiguration** CR configuration:

   Example ImageSetConfiguration CR for LVM Storage

```
kind: ImageSetConfiguration
apiVersion: mirror.openshift.io/v1alpha2
archiveSize: 4 1
storageConfig: 2
  registry:
    imageURL: example.com/mirror/oc-mirror-metadata 3
    skipTLS: false
mirror:
  platform:
    channels:
    - name: stable-4.18 4
      type: ocp
    graph: true 5
  operators:
  - catalog: registry.redhat.io/redhat/redhat-operator-index:v4.18 6
    packages:
    - name: lvms-operator 7
      channels:
      - name: stable 8
  additionalImages:
  - name: registry.redhat.io/ubi9/ubi:latest 9
  helm: {}
```

1. Set the maximum size (in GiB) of each file within the image set.
2. Specify the location in which you want to save the image set. This location can be a registry or a local directory. You must configure the **storageConfig** field unless you are using the Technology Preview OCI feature.
3. Specify the storage URL for the image stream when using a registry. For more information, see *Why use imagestreams*.
4. Specify the channel from which you want to retrieve the OpenShift Container Platform images.
5. Set this field to **true** to generate the OpenShift Update Service (OSUS) graph image. For more information, see *About the OpenShift Update Service* .
6. Specify the Operator catalog from which you want to retrieve the OpenShift Container Platform images.

7 Specify the Operator packages to include in the image set. If this field is empty, all packages in the catalog are retrieved.

8 Specify the channels of the Operator packages to include in the image set. You must include the default channel for the Operator package even if you do not use the bundles in that channel. You can find the default channel by running the following command: **$ oc mirror list operators --catalog=<catalog_name> --package=<package_name>**.

9 Specify any additional images to include in the image set.

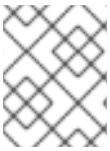
2. Follow the procedure in the "Mirroring an image set to a mirror registry" section.
3. Follow the procedure in the "Configuring image registry repository mirroring" section.

Additional resources

- About disconnected installation mirroring
- Creating a mirror registry with mirror registry for Red Hat OpenShift
- Mirroring the OpenShift Container Platform image repository
- Creating the image set configuration
- Mirroring an image set to a mirror registry
- Configuring image registry repository mirroring
- Why use imagestreams

4.12.4.1.5. Installing LVM Storage by using RHACM

To install LVM Storage on the clusters by using Red Hat Advanced Cluster Management (RHACM), you must create a **Policy** custom resource (CR). You can also configure the criteria to select the clusters on which you want to install LVM Storage.



NOTE

The **Policy** CR that is created to install LVM Storage is also applied to the clusters that are imported or created after creating the **Policy** CR.

Prerequisites

- You have access to the RHACM cluster using an account with **cluster-admin** and Operator installation permissions.
- You have dedicated disks that LVM Storage can use on each cluster.
- The cluster must be managed by RHACM.

Procedure

1. Log in to the RHACM CLI using your OpenShift Container Platform credentials.
2. Create a namespace.

```
$ oc create ns <namespace>
```

3. Create a **Policy** CR YAML file:

Example Policy CR to install and configure LVM Storage

```
apiVersion: apps.open-cluster-management.io/v1
kind: PlacementRule
metadata:
  name: placement-install-lvms
spec:
  clusterConditions:
  - status: "True"
    type: ManagedClusterConditionAvailable
  clusterSelector: (1)
    matchExpressions:
    - key: mykey
      operator: In
      values:
      - myvalue
---
apiVersion: policy.open-cluster-management.io/v1
kind: PlacementBinding
metadata:
  name: binding-install-lvms
placementRef:
  apiGroup: apps.open-cluster-management.io
  kind: PlacementRule
  name: placement-install-lvms
subjects:
- apiGroup: policy.open-cluster-management.io
  kind: Policy
  name: install-lvms
---
apiVersion: policy.open-cluster-management.io/v1
kind: Policy
metadata:
  annotations:
    policy.open-cluster-management.io/categories: CM Configuration Management
    policy.open-cluster-management.io/controls: CM-2 Baseline Configuration
    policy.open-cluster-management.io/standards: NIST SP 800-53
  name: install-lvms
spec:
  disabled: false
  remediationAction: enforce
  policy-templates:
  - objectDefinition:
      apiVersion: policy.open-cluster-management.io/v1
      kind: ConfigurationPolicy
      metadata:
        name: install-lvms
      spec:
        object-templates:
        - complianceType: musthave
          objectDefinition: (2)
```

```
      apiVersion: v1
      kind: Namespace
      metadata:
        labels:
          openshift.io/cluster-monitoring: "true"
          pod-security.kubernetes.io/enforce: privileged
          pod-security.kubernetes.io/audit: privileged
          pod-security.kubernetes.io/warn: privileged
        name: openshift-storage
    - complianceType: musthave
      objectDefinition: 3
        apiVersion: operators.coreos.com/v1
        kind: OperatorGroup
        metadata:
          name: openshift-storage-operatorgroup
          namespace: openshift-storage
        spec:
          targetNamespaces:
          - openshift-storage
    - complianceType: musthave
      objectDefinition: 4
        apiVersion: operators.coreos.com/v1alpha1
        kind: Subscription
        metadata:
          name: lvms
          namespace: openshift-storage
        spec:
          installPlanApproval: Automatic
          name: lvms-operator
          source: redhat-operators
          sourceNamespace: openshift-marketplace
    remediationAction: enforce
    severity: low
```

1. Set the **key** field and **values** field in **PlacementRule.spec.clusterSelector** to match the labels that are configured in the clusters on which you want to install LVM Storage.
2. Namespace configuration.
3. The **OperatorGroup** CR configuration.
4. The **Subscription** CR configuration.

4. Create the **Policy** CR by running the following command:

```
$ oc create -f <file_name> -n <namespace>
```

Upon creating the **Policy** CR, the following custom resources are created on the clusters that match the selection criteria configured in the **PlacementRule** CR:

- **Namespace**
- **OperatorGroup**
- **Subscription**

- Red Hat Advanced Cluster Management for Kubernetes: Installing while connected online
- About the LVMCluster custom resource

4.12.4.2. About the LVMCluster custom resource

You can configure the **LVMCluster** CR to perform the following actions:

- Create LVM volume groups that you can use to provision persistent volume claims (PVCs).
- Configure a list of devices that you want to add to the LVM volume groups.
- Configure the requirements to select the nodes on which you want to create an LVM volume group, and the thin pool configuration for the volume group.
- Force wipe the selected devices.

After you have installed LVM Storage, you must create an **LVMCluster** custom resource (CR).

Example LVMCluster CR YAML file

```
apiVersion: lvm.topolvm.io/v1alpha1
kind: LVMCluster
metadata:
  name: my-lvmcluster
spec:
  tolerations:
  - effect: NoSchedule
    key: xyz
    operator: Equal
    value: "true"
  storage:
    deviceClasses:
    - name: vg1
      fstype: ext4 (1)
      default: true
      nodeSelector: (2)
        nodeSelectorTerms:
        - matchExpressions:
          - key: mykey
            operator: In
            values:
            - ssd
      deviceSelector: (3)
        paths:
        - /dev/disk/by-path/pci-0000:87:00.0-nvme-1
        - /dev/disk/by-path/pci-0000:88:00.0-nvme-1
        optionalPaths:
        - /dev/disk/by-path/pci-0000:89:00.0-nvme-1
        - /dev/disk/by-path/pci-0000:90:00.0-nvme-1
        forceWipeDevicesAndDestroyAllData: true
      thinPoolConfig:
        name: thin-pool-1
        sizePercent: 90 (4)
        overprovisionRatio: 10
```

```
    chunkSize: 128Ki 5
    chunkSizeCalculationPolicy: Static 6
    metadataSize: 1Gi 7
    metadataSizeCalculationPolicy: Host 8
```

1 2 3 4 5 6 7 8 Optional field

Explanation of fields in the LVMCluster CR
The **LVMCluster** CR fields are described in the following table:

Table 4.5. **LVMCluster** CR fields

Field	Type	Description
spec.storage.deviceClasses	**array**	Contains the configuration to assign the local storage devices to the LVM volume groups. LVM Storage creates a storage class and volume snapshot class for each device class that you create.
deviceClasses.name	**string**	Specify a name for the LVM volume group (VG). You can also configure this field to reuse a volume group that you created in the previous installation. For more information, see "Reusing a volume group from the previous LVM Storage installation".
deviceClasses.fstype	**string**	Set this field to **ext4** or **xfs**. By default, this field is set to **xfs**.
deviceClasses.default	**boolean**	Set this field to **true** to indicate that a device class is the default. Otherwise, you can set it to **false**. You can only configure a single default device class.
deviceClasses.nodeSelector	**object**	Contains the configuration to choose the nodes on which you want to create the LVM volume group. If this field is empty, all nodes without no-schedule taints are considered. On the control-plane node, LVM Storage detects and uses the additional worker nodes when the new nodes become active in the cluster.
nodeSelector.nodeSelectorTerms	**array**	Configure the requirements that are used to select the node.

Field	Type	Description
deviceClasses.deviceSelector	**object**	Contains the configuration to perform the following actions: • Specify the paths to the devices that you want to add to the LVM volume group. • Force wipe the devices that are added to the LVM volume group. For more information, see "About adding devices to a volume group".
deviceSelector.paths	**array**	Specify the device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, the **LVMCluster** CR moves to the **Failed** state.
deviceSelector.optionalPaths	**array**	Specify the optional device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, LVM Storage ignores the device without causing an error.
deviceSelector.forceWipeDevicesAndDestroyAllData	**boolean**	LVM Storage uses only those disks that are empty and do not contain file system signatures. To ensure that the disks are empty and do not contain file system signatures, wipe the disks before using them. To force wipe the selected devices, set this field to **true**. By default, this field is set to **false**. **WARNING** If this field is set to **true**, LVM Storage wipes all previous data on the devices. Use this feature with caution. Wiping the device can lead to inconsistencies in data integrity if any of the following conditions are met: • The device is being used as swap space. • The device is part of a RAID array. • The device is mounted. If any of these conditions are true, do not force wipe the disk. Instead, you must manually wipe the disk.

Field	Type	Description
deviceClasses.thinPoolConfig	**object**	Contains the configuration to create a thin pool in the LVM volume group. If you exclude this field, logical volumes are thick provisioned. Using thick-provisioned storage includes the following limitations: ● No copy-on-write support for volume cloning. ● No support for snapshot class. ● No support for over-provisioning. As a result, the provisioned capacity of **PersistentVolumeClaims** (PVCs) is immediately reduced from the volume group. ● No support for thin metrics. Thick-provisioned devices only support volume group metrics.
thinPoolConfig.name	**string**	Specify a name for the thin pool.
thinPoolConfig.sizePercent	**integer**	Specify the percentage of space in the LVM volume group for creating the thin pool. By default, this field is set to 90. The minimum value that you can set is 10, and the maximum value is 90.

thinPoolConfig.overprovisionRatio	**integer**	Specify a factor by which you can provision additional storage based on the available storage in the thin pool.
		
		For example, if this field is set to 10, you can provision up to 10 times the amount of available storage in the thin pool. You can modify this field after the LVM cluster has been created.
		
		To update the parameter, do any of the following tasks:
		
		● To edit the LVM Cluster, run the following command:
		
		`$ oc edit lvmcluster <lvmcluster_name>`
		
		● To apply a patch, run the following command:
		
		`$ oc patch lvmcluster <lvmcluster_name> -p <patch_file.yaml>`
		
		To disable over-provisioning, set this field to 1.

Field	Type	Description
thinPoolConfig.chunkSize	**integer**	Specifies the statically calculated chunk size for the thin pool. This field is only used when the **ChunkSizeCalculationPolicy** field is set to **Static**. The value for this field must be configured in the range of 64 KiB to 1 GiB because of the underlying limitations of **lvm2**. If you do not configure this field and the **ChunkSizeCalculationPolicy** field is set to **Static**, the default chunk size is set to 128 KiB. For more information, see "Overview of chunk size".
thinPoolConfig.chunkSizeCalculationPolicy	**string**	Specifies the policy to calculate the chunk size for the underlying volume group. You can set this field to either **Static** or **Host**. By default, this field is set to **Static**. If this field is set to **Static**, the chunk size is set to the value of the **chunkSize** field. If the **chunkSize** field is not configured, chunk size is set to 128 KiB. If this field is set to **Host**, the chunk size is calculated based on the configuration in the **lvm.conf** file. For more information, see "Limitations to configure the size of the devices used in LVM Storage".
thinPoolConfig.metadataSize	**integer**	Specifies the metadata size for the thin pool. You can configure this field only when the **MetadataSizeCalculationPolicy** field is set to **Static**. If this field is not configured, and the **MetadataSizeCalculationPolicy** field is set to **Static**, the default metadata size is set to 1 GiB. The value for this field must be configured in the range of 2 MiB to 16 GiB due to the underlying limitations of **lvm2**. You can only increase the value of this field during updates.
thinPoolConfig.metadataSizeCalculationPolicy	**string**	Specifies the policy to calculate the metadata size for the underlying volume group. You can set this field to either **Static** or **Host**. By default, this field is set to **Host**. If this field is set to **Static**, the metadata size is calculated based on the value of the **thinPoolConfig.metadataSize** field. If this field is set to **Host**, the metadata size is calculated based on the **lvm2** settings.

Additional resources

- Overview of chunk size

- Limitations to configure the size of the devices used in LVM Storage
- Reusing a volume group from the previous LVM Storage installation
- About adding devices to a volume group
- Adding worker nodes to single-node OpenShift clusters

4.12.4.2.1. Limitations to configure the size of the devices used in LVM Storage

The limitations to configure the size of the devices that you can use to provision storage using LVM Storage are as follows:

- The total storage size that you can provision is limited by the size of the underlying Logical Volume Manager (LVM) thin pool and the over-provisioning factor.
- The size of the logical volume depends on the size of the Physical Extent (PE) and the Logical Extent (LE).
  - You can define the size of PE and LE during the physical and logical device creation.
  - The default PE and LE size is 4 MB.
  - If the size of the PE is increased, the maximum size of the LVM is determined by the kernel limits and your disk space.

The following tables describe the chunk size and volume size limits for static and host configurations:

Table 4.6. Tested configuration

Parameter	Value
Chunk size	128 KiB
Maximum volume size	32 TiB

Table 4.7. Theoretical size limits for static configuration

Parameter	Minimum value	Maximum value
Chunk size	64 KiB	1 GiB
Volume size	Minimum size of the underlying Red Hat Enterprise Linux CoreOS (RHCOS) system.	Maximum size of the underlying RHCOS system.

Table 4.8. Theoretical size limits for a host configuration

Parameter	Value
Chunk size	This value is based on the configuration in the **lvm.conf** file. By default, this value is set to 128 KiB.

Parameter	Value
Maximum volume size	Equal to the maximum volume size of the underlying RHCOS system.
Minimum volume size	Equal to the minimum volume size of the underlying RHCOS system.

4.12.4.2.2. About adding devices to a volume group

The **deviceSelector** field in the **LVMCluster** CR contains the configuration to specify the paths to the devices that you want to add to the Logical Volume Manager (LVM) volume group.

You can specify the device paths in the **deviceSelector.paths** field, the **deviceSelector.optionalPaths** field, or both. If you do not specify the device paths in both the **deviceSelector.paths** field and the **deviceSelector.optionalPaths** field, LVM Storage adds the supported unused devices to the volume group (VG).

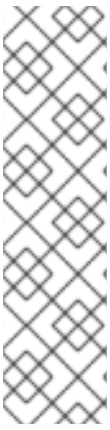
WARNING

It is recommended to avoid referencing disks using symbolic naming, such as **/dev/sdX**, as these names may change across reboots within RHCOS. Instead, you must use stable naming schemes, such as **/dev/disk/by-path/** or **/dev/disk/by-id/**, to ensure consistent disk identification.

With this change, you might need to adjust existing automation workflows in the cases where monitoring collects information about the install device for each node.

For more information, see the RHEL documentation.

You can add the path to the Redundant Array of Independent Disks (RAID) arrays in the **deviceSelector** field to integrate the RAID arrays with LVM Storage. You can create the RAID array by using the **mdadm** utility. LVM Storage does not support creating a software RAID.



NOTE

You can create a RAID array only during an OpenShift Container Platform installation. For information on creating a RAID array, see the following sections:

- "Configuring a RAID-enabled data volume" in "Additional resources".
- Creating a software RAID on an installed system
- Replacing a failed disk in RAID
- Repairing RAID disks

You can also add encrypted devices to the volume group. You can enable disk encryption on the cluster

nodes during an OpenShift Container Platform installation. After encrypting a device, you can specify the path to the LUKS encrypted device in the **deviceSelector** field. For information on disk encryption, see "About disk encryption" and "Configuring disk encryption and mirroring".

The devices that you want to add to the VG must be supported by LVM Storage. For information about unsupported devices, see "Devices not supported by LVM Storage".

LVM Storage adds the devices to the VG only if the following conditions are met:

- The device path exists.
- The device is supported by LVM Storage.

IMPORTANT

After a device is added to the VG, you cannot remove the device.

LVM Storage supports dynamic device discovery. If you do not add the **deviceSelector** field in the **LVMCluster** CR, LVM Storage automatically adds the new devices to the VG when the devices are available.

WARNING

It is not recommended to add the devices to the VG through dynamic device discovery due to the following reasons:

- When you add a new device that you do not intend to add to the VG, LVM Storage automatically adds this device to the VG through dynamic device discovery.
- If LVM Storage adds a device to the VG through dynamic device discovery, LVM Storage does not restrict you from removing the device from the node. Removing or updating the devices that are already added to the VG can disrupt the VG. This can also lead to data loss and necessitate manual node remediation.

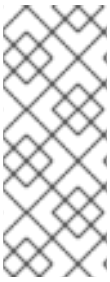
Additional resources

- Configuring a RAID-enabled data volume
- About disk encryption
- Configuring disk encryption and mirroring
- Devices not supported by LVM Storage

4.12.4.2.3. Devices not supported by LVM Storage

When you are adding the device paths in the **deviceSelector** field of the **LVMCluster** custom resource (CR), ensure that the devices are supported by LVM Storage. If you add paths to the unsupported devices, LVM Storage excludes the devices to avoid complexity in managing logical volumes.

If you do not specify any device path in the **deviceSelector** field, LVM Storage adds only the unused devices that it supports.



NOTE

To get information about the devices, run the following command:

```
$ lsblk --paths --json -o \
NAME,ROTA,TYPE,SIZE,MODEL,VENDOR,RO,STATE,KNAME,SERIAL,PARTLABEL
,FSTYPE
```

LVM Storage does not support the following devices:

Read-only devices

Devices with the **ro** parameter set to **true**.

Suspended devices

Devices with the **state** parameter set to **suspended**.

ROM devices

Devices with the **type** parameter set to **rom**.

LVM partition devices

Devices with the **type** parameter set to **lvm**.

Devices with invalid partition labels

Devices with the **partlabel** parameter set to **bios**, **boot**, or **reserved**.

Devices with an invalid filesystem

Devices with the **fstype** parameter set to any value other than **null** or **LVM2_member**.

IMPORTANT

LVM Storage supports devices with **fstype** parameter set to **LVM2_member** only if the devices do not contain children devices.

Devices that are part of another volume group

To get the information about the volume groups of the device, run the following command:

```
$ pvs <device-name> 1
```

1 Replace **<device-name>** with the device name.

Devices with bind mounts

To get the mount points of a device, run the following command:

```
$ cat /proc/1/mountinfo | grep <device-name> 1
```

1 Replace **<device-name>** with the device name.

Devices that contain children devices

NOTE

It is recommended to wipe the device before using it in LVM Storage to prevent unexpected behavior.

4.12.4.3. Ways to create an LVMCluster custom resource

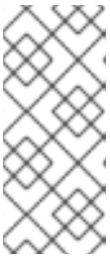
You can create an **LVMCluster** custom resource (CR) by using the OpenShift CLI (**oc**) or the OpenShift Container Platform web console. If you have installed LVM Storage by using Red Hat Advanced Cluster Management (RHACM), you can also create an **LVMCluster** CR by using RHACM.

IMPORTANT

You must create the **LVMCluster** CR in the same namespace where you installed the LVM Storage Operator, which is **openshift-storage** by default.

Upon creating the **LVMCluster** CR, LVM Storage creates the following system-managed CRs:

- A **storageClass** and **volumeSnapshotClass** for each device class.



NOTE

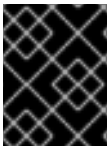
LVM Storage configures the name of the storage class and volume snapshot class in the format **lvms-<device_class_name>**, where, **<device_class_name>** is the value of the **deviceClasses.name** field in the **LVMCluster** CR. For example, if the **deviceClasses.name** field is set to vg1, the name of the storage class and volume snapshot class is **lvms-vg1**.

- **LVMVolumeGroup**: This CR is a specific type of persistent volume (PV) that is backed by an LVM volume group. It tracks the individual volume groups across multiple nodes.
- **LVMVolumeGroupNodeStatus**: This CR tracks the status of the volume groups on a node.

4.12.4.3.1. Reusing a volume group from the previous LVM Storage installation

You can reuse an existing volume group (VG) from the previous LVM Storage installation instead of creating a new VG.

You can only reuse a VG but not the logical volume associated with the VG.



IMPORTANT

You can perform this procedure only while creating an **LVMCluster** custom resource (CR).

Prerequisites

- The VG that you want to reuse must not be corrupted.
- The VG that you want to reuse must have the **lvms** tag. For more information on adding tags to LVM objects, see Grouping LVM objects with tags.

Procedure

1. Open the **LVMCluster** CR YAML file.
2. Configure the **LVMCluster** CR parameters as described in the following example:

Example LVMCluster CR YAML file

```
apiVersion: lvm.topolvm.io/v1alpha1
kind: LVMCluster
metadata:
  name: my-lvmcluster
spec:
# ...
  storage:
    deviceClasses:
    - name: vg1 (1)
      fstype: ext4 (2)
      default: true
      deviceSelector: (3)
# ...
        forceWipeDevicesAndDestroyAllData: false (4)
      thinPoolConfig: (5)
# ...
      nodeSelector: (6)
# ...
```

(1) Set this field to the name of a VG from the previous LVM Storage installation.

(2) Set this field to **ext4** or **xfs**. By default, this field is set to **xfs**.

(3) You can add new devices to the VG that you want to reuse by specifying the new device paths in the **deviceSelector** field. If you do not want to add new devices to the VG, ensure that the **deviceSelector** configuration in the current LVM Storage installation is same as that of the previous LVM Storage installation.

(4) If this field is set to **true**, LVM Storage wipes all the data on the devices that are added to the VG.

(5) To retain the **thinPoolConfig** configuration of the VG that you want to reuse, ensure that the **thinPoolConfig** configuration in the current LVM Storage installation is same as that of the previous LVM Storage installation. Otherwise, you can configure the **thinPoolConfig** field as required.

(6) Configure the requirements to choose the nodes on which you want to create the LVM volume group. If this field is empty, all nodes without no-schedule taints are considered.

3. Save the **LVMCluster** CR YAML file.

NOTE

To view the devices that are part a volume group, run the following command:

```
$ pvs -S vgname=<vg_name> 1
```

1 Replace **<vg_name>** with the name of the volume group.

4.12.4.3.2. Creating an LVMCluster CR by using the CLI

You can create an **LVMCluster** custom resource (CR) on a worker node using the OpenShift CLI (**oc**).

IMPORTANT

You can only create a single instance of the **LVMCluster** custom resource (CR) on an OpenShift Container Platform cluster.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to OpenShift Container Platform as a user with **cluster-admin** privileges.
- You have installed LVM Storage.
- You have installed a worker node in the cluster.
- You read the "About the LVMCluster custom resource" section.

Procedure

1. Create an **LVMCluster** custom resource (CR) YAML file:

Example LVMCluster CR YAML file

```
apiVersion: lvm.topolvm.io/v1alpha1
kind: LVMCluster
metadata:
  name: my-lvmcluster
spec:
# ...
  storage:
    deviceClasses: 1
# ...
      nodeSelector: 2
# ...
      deviceSelector: 3
# ...
      thinPoolConfig: 4
# ...
```

1 Contains the configuration to assign the local storage devices to the LVM volume groups.

2 Contains the configuration to choose the nodes on which you want to create the LVM volume group. If this field is empty, all nodes without no-schedule taints are considered.

3 Contains the configuration to specify the paths to the devices that you want to add to the LVM volume group, and force wipe the devices that are added to the LVM volume group.

4 Contains the configuration to create a thin pool in the LVM volume group. If you exclude this field, logical volumes are thick provisioned.

2. Create the **LVMCluster** CR by running the following command:

```
$ oc create -f <file_name>
```

Example output

```
lvmcluster/lvmcluster created
```

Verification

1. Check that the **LVMCluster** CR is in the **Ready** state:

```
$ oc get lvmclusters.lvm.topolvm.io -o jsonpath='{.items[*].status}' -n <namespace>
```

Example output

```
{"deviceClassStatuses": 1
[
  {
    "name": "vg1",
    "nodeStatus": [ 2
        {
            "devices": [ 3
                "/dev/nvme0n1",
                "/dev/nvme1n1",
                "/dev/nvme2n1"
            ],
            "node": "kube-node", 4
            "status": "Ready" 5
        }
    ]
  }
]
"state":"Ready"} 6
```

1 The status of the device class.

2 The status of the LVM volume group on each node.

3 The list of devices used to create the LVM volume group.

4 The node on which the device class is created.

5 The status of the LVM volume group on the node.

6 The status of the **LVMCluster** CR.

NOTE

If the **LVMCluster** CR is in the **Failed** state, you can view the reason for failure in the **status** field.

Example of **status** field with the reason for failue:

```
status:
  deviceClassStatuses:
    - name: vg1
      nodeStatus:
        - node: my-node-1.example.com
          reason: no available devices found for volume group
          status: Failed
  state: Failed
```

2. Optional: To view the storage classes created by LVM Storage for each device class, run the following command:

```
$ oc get storageclass
```

Example output

```
NAME         PROVISIONER         RECLAIMPOLICY   VOLUMEBINDINGMODE
ALLOWVOLUMEEXPANSION   AGE
lvms-vg1     topolvm.io          Delete          WaitForFirstConsumer   true                   31m
```

3. Optional: To view the volume snapshot classes created by LVM Storage for each device class, run the following command:

```
$ oc get volumesnapshotclass
```

Example output

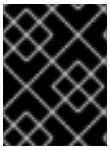
```
NAME         DRIVER            DELETIONPOLICY   AGE
lvms-vg1     topolvm.io        Delete           24h
```

Additional resources

- About the LVMCluster custom resource

4.12.4.3.3. Creating an LVMCluster CR by using the web console

You can create an **LVMCluster** CR on a worker node using the OpenShift Container Platform web console.



IMPORTANT

You can only create a single instance of the **LVMCluster** custom resource (CR) on an OpenShift Container Platform cluster.

Prerequisites

- You have access to the OpenShift Container Platform cluster with **cluster-admin** privileges.
- You have installed LVM Storage.
- You have installed a worker node in the cluster.
- You read the "About the LVMCluster custom resource" section.

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Click **Operators → Installed Operators**.
3. In the **openshift-storage** namespace, click **LVM Storage**.
4. Click **Create LVMCluster** and select either **Form view** or **YAML view**.
5. Configure the required **LVMCluster** CR parameters.
6. Click **Create**.
7. Optional: If you want to edit the **LVMCLuster** CR, perform the following actions:
   a. Click the **LVMCluster** tab.
   b. From the **Actions** menu, select **Edit LVMCluster**.
   c. Click **YAML** and edit the required **LVMCLuster** CR parameters.
   d. Click **Save**.

Verification

1. On the **LVMCLuster** page, check that the **LVMCluster** CR is in the **Ready** state.
2. Optional: To view the available storage classes created by LVM Storage for each device class, click **Storage → StorageClasses**.
3. Optional: To view the available volume snapshot classes created by LVM Storage for each device class, click **Storage → VolumeSnapshotClasses**.

Additional resources

- About the LVMCluster custom resource

4.12.4.3.4. Creating an LVMCluster CR by using RHACM

After you have installed LVM Storage by using RHACM, you must create an **LVMCluster** custom resource (CR).

Prerequisites

- You have installed LVM Storage by using RHACM.
- You have access to the RHACM cluster using an account with **cluster-admin** permissions.
- You read the "About the LVMCluster custom resource" section.

Procedure

1. Log in to the RHACM CLI using your OpenShift Container Platform credentials.
2. Create a **ConfigurationPolicy** CR YAML file with the configuration to create an **LVMCluster** CR:

Example ConfigurationPolicy CR YAML file to create an LVMCluster CR

```
apiVersion: policy.open-cluster-management.io/v1
kind: ConfigurationPolicy
metadata:
  name: lvms
spec:
  object-templates:
  - complianceType: musthave
    objectDefinition:
      apiVersion: lvm.topolvm.io/v1alpha1
      kind: LVMCluster
      metadata:
        name: my-lvmcluster
        namespace: openshift-storage
      spec:
        storage:
          deviceClasses: 1
# ...
            deviceSelector: 2
# ...
            thinPoolConfig: 3
# ...
            nodeSelector: 4
# ...
  remediationAction: enforce
  severity: low
```

1. Contains the configuration to assign the local storage devices to the LVM volume groups.
2. Contains the configuration to specify the paths to the devices that you want to add to the LVM volume group, and force wipe the devices that are added to the LVM volume group.
3. Contains the configuration to create a thin pool in the LVM volume group. If you exclude this field, logical volumes are thick provisioned.
4.

Contains the configuration to choose the nodes on which you want to create the LVM volume groups. If this field is empty, then all nodes without no-schedule taints are

3. Create the **ConfigurationPolicy** CR by running the following command:

```
$ oc create -f <file_name> -n <cluster_namespace>
```
(1)

(1) Namespace of the OpenShift Container Platform cluster on which LVM Storage is installed.

Additional resources

- Red Hat Advanced Cluster Management for Kubernetes: Installing while connected online
- About the LVMCluster custom resource

4.12.4.4. Ways to delete an LVMCluster custom resource

You can delete an **LVMCluster** custom resource (CR) by using the OpenShift CLI (**oc**) or the OpenShift Container Platform web console. If you have installed LVM Storage by using Red Hat Advanced Cluster Management (RHACM), you can also delete an **LVMCluster** CR by using RHACM.

Upon deleting the **LVMCluster** CR, LVM Storage deletes the following CRs:

- **storageClass**
- **volumeSnapshotClass**
- **LVMVolumeGroup**
- **LVMVolumeGroupNodeStatus**

4.12.4.4.1. Deleting an LVMCluster CR by using the CLI

You can delete the **LVMCluster** custom resource (CR) using the OpenShift CLI (**oc**).

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.
- You have deleted the persistent volume claims (PVCs), volume snapshots, and volume clones provisioned by LVM Storage. You have also deleted the applications that are using these resources.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Delete the **LVMCluster** CR by running the following command:

```
$ oc delete lvmcluster <lvm_cluster_name> -n openshift-storage
```

Verification

- To verify that the **LVMCluster** CR has been deleted, run the following command:

```
$ oc get lvmcluster -n <namespace>
```

Example output

```
No resources found in openshift-storage namespace.
```

4.12.4.4.2. Deleting an LVMCluster CR by using the web console

You can delete the **LVMCluster** custom resource (CR) using the OpenShift Container Platform web console.

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.
- You have deleted the persistent volume claims (PVCs), volume snapshots, and volume clones provisioned by LVM Storage. You have also deleted the applications that are using these resources.

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Click **Operators → Installed Operators** to view all the installed Operators.
3. Click **LVM Storage** in the **openshift-storage** namespace.
4. Click the **LVMCluster** tab.
5. From the **Actions**, select **Delete LVMCluster**.
6. Click **Delete**.

Verification

- On the **LVMCLuster** page, check that the **LVMCluster** CR has been deleted.

4.12.4.4.3. Deleting an LVMCluster CR by using RHACM

If you have installed LVM Storage by using Red Hat Advanced Cluster Management (RHACM), you can delete an **LVMCluster** CR by using RHACM.

Prerequisites

- You have access to the RHACM cluster as a user with **cluster-admin** permissions.
- You have deleted the persistent volume claims (PVCs), volume snapshots, and volume clones provisioned by LVM Storage. You have also deleted the applications that are using these resources.

Procedure

1. Log in to the RHACM CLI using your OpenShift Container Platform credentials.
2. Delete the **ConfigurationPolicy** CR YAML file that was created for the **LVMCluster** CR:

```
$ oc delete -f <file_name> -n <cluster_namespace> 1
```

1 Namespace of the OpenShift Container Platform cluster on which LVM Storage is installed.

3. Create a **Policy** CR YAML file to delete the **LVMCluster** CR:

Example Policy CR to delete the LVMCluster CR

```
apiVersion: policy.open-cluster-management.io/v1
kind: Policy
metadata:
  name: policy-lvmcluster-delete
  annotations:
    policy.open-cluster-management.io/standards: NIST SP 800-53
    policy.open-cluster-management.io/categories: CM Configuration Management
    policy.open-cluster-management.io/controls: CM-2 Baseline Configuration
spec:
  remediationAction: enforce
  disabled: false
  policy-templates:
    - objectDefinition:
        apiVersion: policy.open-cluster-management.io/v1
        kind: ConfigurationPolicy
        metadata:
          name: policy-lvmcluster-removal
        spec:
          remediationAction: enforce 1
          severity: low
          object-templates:
            - complianceType: mustnothave
              objectDefinition:
                kind: LVMCluster
                apiVersion: lvm.topolvm.io/v1alpha1
                metadata:
                  name: my-lvmcluster
                  namespace: openshift-storage 2
---
apiVersion: policy.open-cluster-management.io/v1
kind: PlacementBinding
metadata:
  name: binding-policy-lvmcluster-delete
placementRef:
  apiGroup: apps.open-cluster-management.io
  kind: PlacementRule
  name: placement-policy-lvmcluster-delete
subjects:
  - apiGroup: policy.open-cluster-management.io
```

```
    kind: Policy
    name: policy-lvmcluster-delete
---
apiVersion: apps.open-cluster-management.io/v1
kind: PlacementRule
metadata:
  name: placement-policy-lvmcluster-delete
spec:
  clusterConditions:
    - status: "True"
      type: ManagedClusterConditionAvailable
  clusterSelector: 3
    matchExpressions:
      - key: mykey
        operator: In
        values:
          - myvalue
```

1. The **spec.remediationAction** in **policy-template** is overridden by the preceding parameter value for **spec.remediationAction**.
2. This **namespace** field must have the **openshift-storage** value.
3. Configure the requirements to select the clusters. LVM Storage is uninstalled on the clusters that match the selection criteria.

4. Create the **Policy** CR by running the following command:

```
$ oc create -f <file_name> -n <namespace>
```

5. Create a **Policy** CR YAML file to check if the **LVMCluster** CR has been deleted:

Example Policy CR to check if the LVMCluster CR has been deleted

```
apiVersion: policy.open-cluster-management.io/v1
kind: Policy
metadata:
  name: policy-lvmcluster-inform
  annotations:
    policy.open-cluster-management.io/standards: NIST SP 800-53
    policy.open-cluster-management.io/categories: CM Configuration Management
    policy.open-cluster-management.io/controls: CM-2 Baseline Configuration
spec:
  remediationAction: inform
  disabled: false
  policy-templates:
    - objectDefinition:
        apiVersion: policy.open-cluster-management.io/v1
        kind: ConfigurationPolicy
        metadata:
          name: policy-lvmcluster-removal-inform
        spec:
          remediationAction: inform 1
          severity: low
```

```
        object-templates:
          - complianceType: mustnothave
            objectDefinition:
              kind: LVMCluster
              apiVersion: lvm.topolvm.io/v1alpha1
              metadata:
                name: my-lvmcluster
                namespace: openshift-storage (2)
---
apiVersion: policy.open-cluster-management.io/v1
kind: PlacementBinding
metadata:
  name: binding-policy-lvmcluster-check
placementRef:
  apiGroup: apps.open-cluster-management.io
  kind: PlacementRule
  name: placement-policy-lvmcluster-check
subjects:
  - apiGroup: policy.open-cluster-management.io
    kind: Policy
    name: policy-lvmcluster-inform
---
apiVersion: apps.open-cluster-management.io/v1
kind: PlacementRule
metadata:
  name: placement-policy-lvmcluster-check
spec:
  clusterConditions:
    - status: "True"
      type: ManagedClusterConditionAvailable
  clusterSelector:
    matchExpressions:
      - key: mykey
        operator: In
        values:
          - myvalue
```

(1) The **policy-template spec.remediationAction** is overridden by the preceding parameter value for **spec.remediationAction**.

(2) The **namespace** field must have the **openshift-storage** value.

6. Create the **Policy** CR by running the following command:

```
$ oc create -f <file_name> -n <namespace>
```

Verification

- Check the status of the **Policy** CRs by running the following command:

```
$ oc get policy -n <namespace>
```

Example output

```
NAME                        REMEDIATION ACTION   COMPLIANCE STATE   AGE
policy-lvmcluster-delete    enforce              Compliant          15m
policy-lvmcluster-inform    inform               Compliant          15m
```

IMPORTANT

The **Policy** CRs must be in **Compliant** state.

4.12.4.5. Provisioning storage

After you have created the LVM volume groups using the **LVMCluster** custom resource (CR), you can provision the storage by creating persistent volume claims (PVCs).

The following are the minimum storage sizes that you can request for each file system type:

- **block**: 8 MiB
- **xfs**: 300 MiB
- **ext4**: 32 MiB

To create a PVC, you must create a **PersistentVolumeClaim** object.

Prerequisites

- You have created an **LVMCluster** CR.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Create a **PersistentVolumeClaim** object:

Example PersistentVolumeClaim object

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: lvm-block-1 (1)
  namespace: default
spec:
  accessModes:
    - ReadWriteOnce
  volumeMode: Block (2)
  resources:
    requests:
      storage: 10Gi (3)
    limits:
      storage: 20Gi (4)
  storageClassName: lvms-vg1 (5)
```

(1) Specify a name for the PVC.

(2)

To create a block PVC, set this field to **Block**. To create a file PVC, set this field to **Filesystem**.

3 Specify the storage size. If the value is less than the minimum storage size, the requested storage size is rounded to the minimum storage size. The total storage size you can provision is limited by the size of the Logical Volume Manager (LVM) thin pool and the over-provisioning factor.

4 Optional: Specify the storage limit. Set this field to a value that is greater than or equal to the minimum storage size. Otherwise, PVC creation fails with an error.

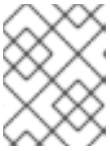
5 The value of the **storageClassName** field must be in the format **lvms-<device_class_name>** where **<device_class_name>** is the value of the **deviceClasses.name** field in the **LVMCluster** CR. For example, if the **deviceClasses.name** field is set to **vg1**, you must set the **storageClassName** field to **lvms-vg1**.

NOTE

The **volumeBindingMode** field of the storage class is set to **WaitForFirstConsumer**.

3. Create the PVC by running the following command:

```
# oc create -f <file_name> -n <application_namespace>
```



NOTE

The created PVCs remain in **Pending** state until you deploy the pods that use them.

Verification

- To verify that the PVC is created, run the following command:

```
$ oc get pvc -n <namespace>
```

Example output

```
NAME          STATUS   VOLUME                                     CAPACITY   ACCESS MODES
STORAGECLASS   AGE
lvm-block-1   Bound    pvc-e90169a8-fd71-4eea-93b8-817155f60e47   1Gi        RWO
lvms-vg1       5s
```

4.12.4.6. Ways to scale up the storage of clusters

OpenShift Container Platform supports additional worker nodes for clusters on bare metal user-provisioned infrastructure. You can scale up the storage of clusters either by adding new worker nodes with available storage or by adding new devices to the existing worker nodes.

Logical Volume Manager (LVM) Storage detects and uses additional worker nodes when the nodes become active.

To add a new device to the existing worker nodes on a cluster, you must add the path to the new device in the **deviceSelector** field of the **LVMCluster** custom resource (CR).

IMPORTANT

You can add the **deviceSelector** field in the **LVMCluster** CR only while creating the **LVMCluster** CR. If you have not added the **deviceSelector** field while creating the **LVMCluster** CR, you must delete the **LVMCluster** CR and create a new **LVMCluster** CR containing the **deviceSelector** field.

If you do not add the **deviceSelector** field in the **LVMCluster** CR, LVM Storage automatically adds the new devices when the devices are available.

NOTE

LVM Storage adds only the supported devices. For information about unsupported devices, see "Devices not supported by LVM Storage".

Additional resources

- Adding worker nodes to single-node OpenShift clusters
- Devices not supported by LVM Storage

4.12.4.6.1. Scaling up the storage of clusters by using the CLI

You can scale up the storage capacity of the worker nodes on a cluster by using the OpenShift CLI (**oc**).

Prerequisites

- You have additional unused devices on each cluster to be used by Logical Volume Manager (LVM) Storage.
- You have installed the OpenShift CLI (**oc**).
- You have created an **LVMCluster** custom resource (CR).

Procedure

1. Edit the **LVMCluster** CR by running the following command:

```
$ oc edit <lvmcluster_file_name> -n <namespace>
```

2. Add the path to the new device in the **deviceSelector** field.

Example LVMCluster CR

```
apiVersion: lvm.topolvm.io/v1alpha1
kind: LVMCluster
metadata:
  name: my-lvmcluster
spec:
  storage:
    deviceClasses:
```

```
# ...
    deviceSelector: 1
      paths: 2
      - /dev/disk/by-path/pci-0000:87:00.0-nvme-1
      - /dev/disk/by-path/pci-0000:88:00.0-nvme-1
      optionalPaths: 3
      - /dev/disk/by-path/pci-0000:89:00.0-nvme-1
      - /dev/disk/by-path/pci-0000:90:00.0-nvme-1
# ...
```

1. Contains the configuration to specify the paths to the devices that you want to add to the LVM volume group. You can specify the device paths in the **paths** field, the **optionalPaths** field, or both. If you do not specify the device paths in both **paths** and **optionalPaths**, Logical Volume Manager (LVM) Storage adds the supported unused devices to the LVM volume group. LVM Storage adds the devices to the LVM volume group only if the following conditions are met:

    - The device path exists.
    - The device is supported by LVM Storage. For information about unsupported devices, see "Devices not supported by LVM Storage".

2. Specify the device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, the **LVMCluster** CR moves to the **Failed** state.

3. Specify the optional device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, LVM Storage ignores the device without causing an error.

IMPORTANT

After a device is added to the LVM volume group, it cannot be removed.

3. Save the **LVMCluster** CR.

Additional resources

- About the LVMCluster custom resource
- Devices not supported by LVM Storage
- About adding devices to a volume group

4.12.4.6.2. Scaling up the storage of clusters by using the web console

You can scale up the storage capacity of the worker nodes on a cluster by using the OpenShift Container Platform web console.

Prerequisites

- You have additional unused devices on each cluster to be used by Logical Volume Manager (LVM) Storage.
- You have created an **LVMCluster** custom resource (CR).

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Click **Operators → Installed Operators**.
3. Click **LVM Storage** in the **openshift-storage** namespace.
4. Click the **LVMCluster** tab to view the **LVMCluster** CR created on the cluster.
5. From the **Actions** menu, select **Edit LVMCluster**.
6. Click the **YAML** tab.
7. Edit the **LVMCluster** CR to add the new device path in the **deviceSelector** field:

Example LVMCluster CR

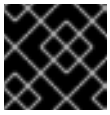
```
apiVersion: lvm.topolvm.io/v1alpha1
kind: LVMCluster
metadata:
  name: my-lvmcluster
spec:
  storage:
    deviceClasses:
# ...
      deviceSelector: (1)
        paths: (2)
        - /dev/disk/by-path/pci-0000:87:00.0-nvme-1
        - /dev/disk/by-path/pci-0000:88:00.0-nvme-1
        optionalPaths: (3)
        - /dev/disk/by-path/pci-0000:89:00.0-nvme-1
        - /dev/disk/by-path/pci-0000:90:00.0-nvme-1
# ...
```

(1) Contains the configuration to specify the paths to the devices that you want to add to the LVM volume group. You can specify the device paths in the **paths** field, the **optionalPaths** field, or both. If you do not specify the device paths in both **paths** and **optionalPaths**, Logical Volume Manager (LVM) Storage adds the supported unused devices to the LVM volume group. LVM Storage adds the devices to the LVM volume group only if the following conditions are met:

- The device path exists.
- The device is supported by LVM Storage. For information about unsupported devices, see "Devices not supported by LVM Storage".

(2) Specify the device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, the **LVMCluster** CR moves to the **Failed** state.

(3) Specify the optional device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, LVM Storage ignores the device without causing an error.



IMPORTANT

After a device is added to the LVM volume group, it cannot be removed.

8. Click **Save**.

Additional resources

- About the LVMCluster custom resource
- Devices not supported by LVM Storage
- About adding devices to a volume group

4.12.4.6.3. Scaling up the storage of clusters by using RHACM

You can scale up the storage capacity of worker nodes on the clusters by using RHACM.

Prerequisites

- You have access to the RHACM cluster using an account with **cluster-admin** privileges.
- You have created an **LVMCluster** custom resource (CR) by using RHACM.
- You have additional unused devices on each cluster to be used by Logical Volume Manager (LVM) Storage.

Procedure

1. Log in to the RHACM CLI using your OpenShift Container Platform credentials.
2. Edit the **LVMCluster** CR that you created using RHACM by running the following command:

```
$ oc edit -f <file_name> -n <namespace>
```
(1)

(1) Replace **<file_name>** with the name of the **LVMCluster** CR.

3. In the **LVMCluster** CR, add the path to the new device in the **deviceSelector** field.

Example LVMCluster CR

```
apiVersion: policy.open-cluster-management.io/v1
kind: ConfigurationPolicy
metadata:
  name: lvms
spec:
  object-templates:
    - complianceType: musthave
      objectDefinition:
        apiVersion: lvm.topolvm.io/v1alpha1
        kind: LVMCluster
        metadata:
          name: my-lvmcluster
```

```
    namespace: openshift-storage
  spec:
    storage:
      deviceClasses:
# ...
        deviceSelector: (1)
          paths: (2)
          - /dev/disk/by-path/pci-0000:87:00.0-nvme-1
          optionalPaths: (3)
          - /dev/disk/by-path/pci-0000:89:00.0-nvme-1
# ...
```

(1) Contains the configuration to specify the paths to the devices that you want to add to the LVM volume group. You can specify the device paths in the **paths** field, the **optionalPaths** field, or both. If you do not specify the device paths in both **paths** and **optionalPaths**, Logical Volume Manager (LVM) Storage adds the supported unused devices to the LVM volume group. LVM Storage adds the devices to the LVM volume group only if the following conditions are met:

- The device path exists.
- The device is supported by LVM Storage. For information about unsupported devices, see "Devices not supported by LVM Storage".

(2) Specify the device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, the **LVMCluster** CR moves to the **Failed** state.

(3) Specify the optional device paths. If the device path specified in this field does not exist, or the device is not supported by LVM Storage, LVM Storage ignores the device without causing an error.

IMPORTANT

After a device is added to the LVM volume group, it cannot be removed.

4. Save the **LVMCluster** CR.

Additional resources

- Red Hat Advanced Cluster Management for Kubernetes: Installing while connected online
- About the LVMCluster custom resource
- Devices not supported by LVM Storage
- About adding devices to a volume group

4.12.4.7. Expanding a persistent volume claim

After scaling up the storage of a cluster, you can expand the existing persistent volume claims (PVCs).

To expand a PVC, you must update the **storage** field in the PVC.

Prerequisites

- Dynamic provisioning is used.
- The **StorageClass** object associated with the PVC has the **allowVolumeExpansion** field set to **true**.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Update the value of the **spec.resources.requests.storage** field to a value that is greater than the current value by running the following command:

```
$ oc patch pvc <pvc_name> -n <application_namespace> \ 1
  --type=merge -p \ '{ "spec": { "resources": { "requests": { "storage": "<desired_size>" }}}}' 2
```

1. Replace **<pvc_name>** with the name of the PVC that you want to expand.
2. Replace **<desired_size>** with the new size to expand the PVC.

Verification

- To verify that resizing is completed, run the following command:

```
$ oc get pvc <pvc_name> -n <application_namespace> -o=jsonpath=
{.status.capacity.storage}
```

  LVM Storage adds the **Resizing** condition to the PVC during expansion. It deletes the **Resizing** condition after the PVC expansion.

Additional resources

- Ways to scale up the storage of clusters
- Enabling volume expansion support

4.12.4.8. Deleting a persistent volume claim

You can delete a persistent volume claim (PVC) by using the OpenShift CLI (**oc**).

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Delete the PVC by running the following command:

```
$ oc delete pvc <pvc_name> -n <namespace>
```

Verification

- To verify that the PVC is deleted, run the following command:

```
$ oc get pvc -n <namespace>
```

  The deleted PVC must not be present in the output of this command.

4.12.4.9. About volume snapshots

You can create snapshots of persistent volume claims (PVCs) that are provisioned by LVM Storage.

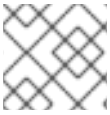
You can perform the following actions using the volume snapshots:

- Back up your application data.

IMPORTANT

Volume snapshots are located on the same devices as the original data. To use the volume snapshots as backups, you must move the snapshots to a secure location. You can use OpenShift API for Data Protection (OADP) backup and restore solutions. For information about OADP, see "OADP features".

- Revert to a state at which the volume snapshot was taken.



NOTE

You can also create volume snapshots of the volume clones.

4.12.4.9.1. Limitations for creating volume snapshots in multi-node topology

LVM Storage has the following limitations for creating volume snapshots in multi-node topology:

- Creating volume snapshots is based on the LVM thin pool capabilities.
- After creating a volume snapshot, the node must have additional storage space for further updating the original data source.
- You can create volume snapshots only on the node where you have deployed the original data source.
- Pods relying on the PVC that uses the snapshot data can be scheduled only on the node where you have deployed the original data source.

Additional resources

- OADP features

4.12.4.9.2. Creating volume snapshots

You can create volume snapshots based on the available capacity of the thin pool and the over-provisioning limits. To create a volume snapshot, you must create a **VolumeSnapshotClass** object.

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.
- You ensured that the persistent volume claim (PVC) is in **Bound** state. This is required for a consistent snapshot.
- You stopped all the I/O to the PVC.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Create a **VolumeSnapshot** object:

   Example VolumeSnapshot object

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
  name: lvm-block-1-snap 1
spec:
  source:
    persistentVolumeClaimName: lvm-block-1 2
  volumeSnapshotClassName: lvms-vg1 3
```

   1. Specify a name for the volume snapshot.
   2. Specify the name of the source PVC. LVM Storage creates a snapshot of this PVC.
   3. Set this field to the name of a volume snapshot class.

   NOTE

   To get the list of available volume snapshot classes, run the following command:

```
$ oc get volumesnapshotclass
```

3. Create the volume snapshot in the namespace where you created the source PVC by running the following command:

```
$ oc create -f <file_name> -n <namespace>
```

   LVM Storage creates a read-only copy of the PVC as a volume snapshot.

Verification

- To verify that the volume snapshot is created, run the following command:

```
$ oc get volumesnapshot -n <namespace>
```

   Example output

```
NAME              READYTOUSE   SOURCEPVC     SOURCESNAPSHOTCONTENT
```

```
RESTORESIZE   SNAPSHOTCLASS   SNAPSHOTCONTENT
CREATIONTIME   AGE
lvm-block-1-snap   true        lvms-test-1                    1Gi          lvms-vg1
snapcontent-af409f97-55fc-40cf-975f-71e44fa2ca91   19s          19s
```

The value of the **READYTOUSE** field for the volume snapshot that you created must be **true**.

4.12.4.9.3. Restoring volume snapshots

To restore a volume snapshot, you must create a persistent volume claim (PVC) with the **dataSource.name** field set to the name of the volume snapshot.

The restored PVC is independent of the volume snapshot and the source PVC.

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.
- You have created a volume snapshot.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Create a **PersistentVolumeClaim** object with the configuration to restore the volume snapshot:

Example PersistentVolumeClaim object to restore a volume snapshot

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: lvm-block-1-restore
spec:
  accessModes:
  - ReadWriteOnce
  volumeMode: Block
  Resources:
    Requests:
      storage: 2Gi (1)
  storageClassName: lvms-vg1 (2)
  dataSource:
    name: lvm-block-1-snap (3)
    kind: VolumeSnapshot
    apiGroup: snapshot.storage.k8s.io
```

(1) Specify the storage size of the restored PVC. The storage size of the requested PVC must be greater than or equal to the stoage size of the volume snapshot that you want to restore. If a larger PVC is required, you can also resize the PVC after restoring the volume snapshot.

(2) Set this field to the value of the **storageClassName** field in the source PVC of the volume snapshot that you want to restore.

3 Set this field to the name of the volume snapshot that you want to restore.

3. Create the PVC in the namespace where you created the volume snapshot by running the following command:

```
$ oc create -f <file_name> -n <namespace>
```

Verification

- To verify that the volume snapshot is restored, run the following command:

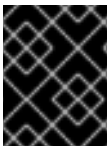
```
$ oc get pvc -n <namespace>
```

Example output

```
NAME                  STATUS   VOLUME                                     CAPACITY   ACCESS MODES
STORAGECLASS   AGE
lvm-block-1-restore   Bound    pvc-e90169a8-fd71-4eea-93b8-817155f60e47   1Gi        RWO
lvms-vg1       5s
```

4.12.4.9.4. Deleting volume snapshots

You can delete the volume snapshots of the persistent volume claims (PVCs).



IMPORTANT

When you delete a persistent volume claim (PVC), LVM Storage deletes only the PVC, but not the snapshots of the PVC.

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.
- You have ensured that the volume snpashot that you want to delete is not in use.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Delete the volume snapshot by running the following command:

```
$ oc delete volumesnapshot <volume_snapshot_name> -n <namespace>
```

Verification

- To verify that the volume snapshot is deleted, run the following command:

```
$ oc get volumesnapshot -n <namespace>
```

The deleted volume snapshot must not be present in the output of this command.

4.12.4.10. About volume clones

A volume clone is a duplicate of an existing persistent volume claim (PVC). You can create a volume clone to make a point-in-time copy of the data.

4.12.4.10.1. Limitations for creating volume clones in multi-node topology

LVM Storage has the following limitations for creating volume clones in multi-node topology:

- Creating volume clones is based on the LVM thin pool capabilities.
- The node must have additional storage after creating a volume clone for further updating the original data source.
- You can create volume clones only on the node where you have deployed the original data source.
- Pods relying on the PVC that uses the clone data can be scheduled only on the node where you have deployed the original data source.

4.12.4.10.2. Creating volume clones

To create a clone of a persistent volume claim (PVC), you must create a **PersistentVolumeClaim** object in the namespace where you created the source PVC.

IMPORTANT

The cloned PVC has write access.

Prerequisites

- You ensured that the source PVC is in **Bound** state. This is required for a consistent clone.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Create a **PersistentVolumeClaim** object:

Example PersistentVolumeClaim object to create a volume clone

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: lvm-pvc-clone
spec:
  accessModes:
  - ReadWriteOnce
  storageClassName: lvms-vg1 1
  volumeMode: Filesystem 2
  dataSource:
    kind: PersistentVolumeClaim
    name: lvm-pvc 3
```

```
  resources:
    requests:
      storage: 1Gi 4
```

1. Set this field to the value of the **storageClassName** field in the source PVC.
2. Set this field to the **volumeMode** field in the source PVC.
3. Specify the name of the source PVC.
4. Specify the storage size for the cloned PVC. The storage size of the cloned PVC must be greater than or equal to the storage size of the source PVC.

3. Create the PVC in the namespace where you created the source PVC by running the following command:

```
$ oc create -f <file_name> -n <namespace>
```

Verification

- To verify that the volume clone is created, run the following command:

```
$ oc get pvc -n <namespace>
```

Example output

```
NAME                STATUS   VOLUME                                     CAPACITY   ACCESS MODES
STORAGECLASS   AGE
lvm-block-1-clone   Bound    pvc-e90169a8-fd71-4eea-93b8-817155f60e47   1Gi        RWO
lvms-vg1       5s
```

4.12.4.10.3. Deleting volume clones

You can delete volume clones.

IMPORTANT

When you delete a persistent volume claim (PVC), LVM Storage deletes only the source persistent volume claim (PVC) but not the clones of the PVC.

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Delete the cloned PVC by running the following command:

```
# oc delete pvc <clone_pvc_name> -n <namespace>
```

Verification

- To verify that the volume clone is deleted, run the following command:

```
$ oc get pvc -n <namespace>
```

  The deleted volume clone must not be present in the output of this command.

4.12.4.11. Updating LVM Storage

You can update LVM Storage to ensure compatibility with the OpenShift Container Platform version.

Prerequisites

- You have updated your OpenShift Container Platform cluster.
- You have installed a previous version of LVM Storage.
- You have installed the OpenShift CLI (**oc**).
- You have access to the cluster using an account with **cluster-admin** permissions.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Update the **Subscription** custom resource (CR) that you created while installing LVM Storage by running the following command:

```
$ oc patch subscription lvms-operator -n openshift-storage --type merge --patch '{"spec":
{"channel":"<update_channel>"}}' 1
```

   1 Replace **<update_channel>** with the version of LVM Storage that you want to install. For example, **stable-4.18**.

3. View the update events to check that the installation is complete by running the following command:

```
$ oc get events -n openshift-storage
```

Example output

```
...
8m13s       Normal    RequirementsUnknown    clusterserviceversion/lvms-operator.v4.18
requirements not yet checked
8m11s       Normal    RequirementsNotMet     clusterserviceversion/lvms-operator.v4.18   one
or more requirements couldn't be found
7m50s       Normal    AllRequirementsMet     clusterserviceversion/lvms-operator.v4.18   all
requirements found, attempting install
7m50s       Normal    InstallSucceeded       clusterserviceversion/lvms-operator.v4.18   waiting
for install components to report healthy
7m49s       Normal    InstallWaiting         clusterserviceversion/lvms-operator.v4.18   installing:
waiting for deployment lvms-operator to become ready: deployment "lvms-operator" waiting
for 1 outdated replica(s) to be terminated
```

```
7m39s Normal InstallSucceeded clusterserviceversion/lvms-operator.v4.18 install strategy completed with no errors
...
```

Verification

- Verify the LVM Storage version by running the following command:

```
$ oc get subscription lvms-operator -n openshift-storage -o jsonpath='{.status.installedCSV}'
```

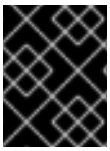
Example output

```
lvms-operator.v4.18
```

4.12.4.12. Monitoring LVM Storage

To enable cluster monitoring, you must add the following label in the namespace where you have installed LVM Storage:

```
openshift.io/cluster-monitoring=true
```



IMPORTANT

For information about enabling cluster monitoring in RHACM, see Observability and Adding custom metrics.

4.12.4.12.1. Metrics

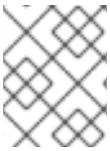
You can monitor LVM Storage by viewing the metrics.

The following table describes the **topolvm** metrics:

Table 4.9. topolvm metrics

Alert	Description
topolvm_thinpool_data_percent	Indicates the percentage of data space used in the LVM thinpool.
topolvm_thinpool_metadata_percent	Indicates the percentage of metadata space used in the LVM thinpool.
topolvm_thinpool_size_bytes	Indicates the size of the LVM thin pool in bytes.
topolvm_volumegroup_available_bytes	Indicates the available space in the LVM volume group in bytes.
topolvm_volumegroup_size_bytes	Indicates the size of the LVM volume group in bytes.

Alert	Description
topolvm_thinpool_overprovisioned_available	Indicates the available over-provisioned size of the LVM thin pool in bytes.



NOTE

Metrics are updated every 10 minutes or when there is a change, such as a new logical volume creation, in the thin pool.

4.12.4.12.2. Alerts

When the thin pool and volume group reach maximum storage capacity, further operations fail. This can lead to data loss.

LVM Storage sends the following alerts when the usage of the thin pool and volume group exceeds a certain value:

Table 4.10. LVM Storage alerts

Alert	Description
VolumeGroupUsageAtThresholdNearFull	This alert is triggered when both the volume group and thin pool usage exceeds 75% on nodes. Data deletion or volume group expansion is required.
VolumeGroupUsageAtThresholdCritical	This alert is triggered when both the volume group and thin pool usage exceeds 85% on nodes. In this case, the volume group is critically full. Data deletion or volume group expansion is required.
ThinPoolDataUsageAtThresholdNearFull	This alert is triggered when the thin pool data uusage in the volume group exceeds 75% on nodes. Data deletion or thin pool expansion is required.
ThinPoolDataUsageAtThresholdCritical	This alert is triggered when the thin pool data usage in the volume group exceeds 85% on nodes. Data deletion or thin pool expansion is required.
ThinPoolMetaDataUsageAtThresholdNearFull	This alert is triggered when the thin pool metadata usage in the volume group exceeds 75% on nodes. Data deletion or thin pool expansion is required.
ThinPoolMetaDataUsageAtThresholdCritical	This alert is triggered when the thin pool metadata usage in the volume group exceeds 85% on nodes. Data deletion or thin pool expansion is required.

4.12.4.13. Uninstalling LVM Storage by using the CLI

You can uninstall LVM Storage by using the OpenShift CLI (**oc**).

Prerequisites

- You have logged in to **oc** as a user with **cluster-admin** permissions.
- You deleted the persistent volume claims (PVCs), volume snapshots, and volume clones provisioned by LVM Storage. You have also deleted the applications that are using these resources.
- You deleted the **LVMCluster** custom resource (CR).

Procedure

1. Get the **currentCSV** value for the LVM Storage Operator by running the following command:

```
$ oc get subscription.operators.coreos.com lvms-operator -n <namespace> -o yaml | grep currentCSV
```

Example output

```
currentCSV: lvms-operator.v4.15.3
```

2. Delete the subscription by running the following command:

```
$ oc delete subscription.operators.coreos.com lvms-operator -n <namespace>
```

Example output

```
subscription.operators.coreos.com "lvms-operator" deleted
```

3. Delete the CSV for the LVM Storage Operator in the target namespace by running the following command:

```
$ oc delete clusterserviceversion <currentCSV> -n <namespace> 1
```

1 Replace **<currentCSV>** with the **currentCSV** value for the LVM Storage Operator.

Example output

```
clusterserviceversion.operators.coreos.com "lvms-operator.v4.15.3" deleted
```

Verification

- To verify that the LVM Storage Operator is uninstalled, run the following command:

```
$ oc get csv -n <namespace>
```

If the LVM Storage Operator was successfully uninstalled, it does not appear in the output of this command.

4.12.4.14. Uninstalling LVM Storage by using the web console

You can uninstall LVM Storage using the OpenShift Container Platform web console.

Prerequisites

- You have access to OpenShift Container Platform as a user with **cluster-admin** permissions.
- You have deleted the persistent volume claims (PVCs), volume snapshots, and volume clones provisioned by LVM Storage. You have also deleted the applications that are using these resources.
- You have deleted the **LVMCluster** custom resource (CR).

Procedure

1. Log in to the OpenShift Container Platform web console.
2. Click **Operators → Installed Operators**.
3. Click **LVM Storage** in the **openshift-storage** namespace.
4. Click the **Details** tab.
5. From the **Actions** menu, select **Uninstall Operator**.
6. Optional: When prompted, select the **Delete all operand instances for this operator**checkbox to delete the operand instances for LVM Storage.
7. Click **Uninstall**.

4.12.4.15. Uninstalling LVM Storage installed using RHACM

To uninstall LVM Storage that you installed using RHACM, you must delete the RHACM **Policy** custom resource (CR) that you created for installing and configuring LVM Storage.

Prerequisites

- You have access to the RHACM cluster as a user with **cluster-admin** permissions.
- You have deleted the persistent volume claims (PVCs), volume snapshots, and volume clones provisioned by LVM Storage. You have also deleted the applications that are using these resources.
- You have deleted the **LVMCluster** CR that you created using RHACM.

Procedure

1. Log in to the OpenShift CLI (**oc**).
2. Delete the RHACM **Policy** CR that you created for installing and configuring LVM Storage by using the following command:

```
$ oc delete -f <policy> -n <namespace>
```
(1)

(1) Replace **<policy>** with the name of the **Policy** CR YAML file.

3. Create a **Policy** CR YAML file with the configuration to uninstall LVM Storage:

Example Policy CR to uninstall LVM Storage

```
apiVersion: apps.open-cluster-management.io/v1
kind: PlacementRule
metadata:
  name: placement-uninstall-lvms
spec:
  clusterConditions:
  - status: "True"
    type: ManagedClusterConditionAvailable
  clusterSelector:
    matchExpressions:
    - key: mykey
      operator: In
      values:
      - myvalue
---
apiVersion: policy.open-cluster-management.io/v1
kind: PlacementBinding
metadata:
  name: binding-uninstall-lvms
placementRef:
  apiGroup: apps.open-cluster-management.io
  kind: PlacementRule
  name: placement-uninstall-lvms
subjects:
- apiGroup: policy.open-cluster-management.io
  kind: Policy
  name: uninstall-lvms
---
apiVersion: policy.open-cluster-management.io/v1
kind: Policy
metadata:
  annotations:
    policy.open-cluster-management.io/categories: CM Configuration Management
    policy.open-cluster-management.io/controls: CM-2 Baseline Configuration
    policy.open-cluster-management.io/standards: NIST SP 800-53
  name: uninstall-lvms
spec:
  disabled: false
  policy-templates:
  - objectDefinition:
      apiVersion: policy.open-cluster-management.io/v1
      kind: ConfigurationPolicy
      metadata:
        name: uninstall-lvms
      spec:
        object-templates:
        - complianceType: mustnothave
          objectDefinition:
            apiVersion: v1
            kind: Namespace
            metadata:
              name: openshift-storage
```

```
      - complianceType: mustnothave
        objectDefinition:
          apiVersion: operators.coreos.com/v1
          kind: OperatorGroup
          metadata:
            name: openshift-storage-operatorgroup
            namespace: openshift-storage
          spec:
            targetNamespaces:
            - openshift-storage
      - complianceType: mustnothave
        objectDefinition:
          apiVersion: operators.coreos.com/v1alpha1
          kind: Subscription
          metadata:
            name: lvms-operator
            namespace: openshift-storage
      remediationAction: enforce
      severity: low
  - objectDefinition:
      apiVersion: policy.open-cluster-management.io/v1
      kind: ConfigurationPolicy
      metadata:
        name: policy-remove-lvms-crds
      spec:
        object-templates:
        - complianceType: mustnothave
          objectDefinition:
            apiVersion: apiextensions.k8s.io/v1
            kind: CustomResourceDefinition
            metadata:
              name: logicalvolumes.topolvm.io
        - complianceType: mustnothave
          objectDefinition:
            apiVersion: apiextensions.k8s.io/v1
            kind: CustomResourceDefinition
            metadata:
              name: lvmclusters.lvm.topolvm.io
        - complianceType: mustnothave
          objectDefinition:
            apiVersion: apiextensions.k8s.io/v1
            kind: CustomResourceDefinition
            metadata:
              name: lvmvolumegroupnodestatuses.lvm.topolvm.io
        - complianceType: mustnothave
          objectDefinition:
            apiVersion: apiextensions.k8s.io/v1
            kind: CustomResourceDefinition
            metadata:
              name: lvmvolumegroups.lvm.topolvm.io
        remediationAction: enforce
        severity: high
```

4. Create the **Policy** CR by running the following command:

```
$ oc create -f <policy> -ns <namespace>
```

-

4.12.4.16. Downloading log files and diagnostic information using must-gather

When LVM Storage is unable to automatically resolve a problem, use the must-gather tool to collect the log files and diagnostic information so that you or the Red Hat Support can review the problem and determine a solution.

Procedure

- Run the **must-gather** command from the client connected to the LVM Storage cluster:

```
$ oc adm must-gather --image=registry.redhat.io/lvms4/lvms-must-gather-rhel9:v4.18 --dest-dir=<directory_name>
```

Additional resources

- About the must-gather tool

4.12.4.17. Troubleshooting persistent storage

While configuring persistent storage using Logical Volume Manager (LVM) Storage, you can encounter several issues that require troubleshooting.

4.12.4.17.1. Investigating a PVC stuck in the Pending state

A persistent volume claim (PVC) can get stuck in the **Pending** state for the following reasons:

- Insufficient computing resources.
- Network problems.
- Mismatched storage class or node selector.
- No available persistent volumes (PVs).
- The node with the PV is in the **Not Ready** state.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to the OpenShift CLI (**oc**) as a user with **cluster-admin** permissions.

Procedure

1. Retrieve the list of PVCs by running the following command:

```
$ oc get pvc
```

Example output

```
NAME        STATUS    VOLUME   CAPACITY   ACCESS MODES   STORAGECLASS   AGE
lvms-test   Pending                                      lvms-vg1       11s
```

2. Inspect the events associated with a PVC stuck in the **Pending** state by running the following command:

```
$ oc describe pvc <pvc_name> 1
```

1 Replace **<pvc_name>** with the name of the PVC. For example, **lvms-vg1**.

Example output

```
Type     Reason              Age              From                         Message
----     ------              ----             ----                         -------
Warning  ProvisioningFailed  4s (x2 over 17s)  persistentvolume-controller
storageclass.storage.k8s.io "lvms-vg1" not found
```

4.12.4.17.2. Recovering from a missing storage class

If you encounter the **storage class not found** error, check the **LVMCluster** custom resource (CR) and ensure that all the Logical Volume Manager (LVM) Storage pods are in the **Running** state.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to the OpenShift CLI (**oc**) as a user with **cluster-admin** permissions.

Procedure

1. Verify that the **LVMCluster** CR is present by running the following command:

```
$ oc get lvmcluster -n openshift-storage
```

Example output

```
NAME           AGE
my-lvmcluster  65m
```

2. If the **LVMCluster** CR is not present, create an **LVMCluster** CR. For more information, see "Ways to create an LVMCluster custom resource".

3. In the **openshift-storage** namespace, check that all the LVM Storage pods are in the **Running** state by running the following command:

```
$ oc get pods -n openshift-storage
```

Example output

```
NAME                                  READY   STATUS    RESTARTS      AGE
lvms-operator-7b9fb858cb-6nsml        3/3     Running   0             70m
topolvm-controller-5dd9cf78b5-7wwr2   5/5     Running   0             66m
topolvm-node-dr26h                    4/4     Running   0             66m
vg-manager-r6zdv                      1/1     Running   0             66m
```

The output of this command must contain a running instance of the following pods:

- **lvms-operator**
- **vg-manager**
  If the **vg-manager** pod is stuck while loading a configuration file, it is due to a failure to locate an available disk for LVM Storage to use. To retrieve the necessary information to troubleshoot this issue, review the logs of the **vg-manager** pod by running the following command:

```
$ oc logs -l app.kubernetes.io/component=vg-manager -n openshift-storage
```

Additional resources

- About the LVMCluster custom resource
- Ways to create an LVMCluster custom resource

4.12.4.17.3. Recovering from node failure

A persistent volume claim (PVC) can be stuck in the **Pending** state due to a node failure in the cluster.

To identify the failed node, you can examine the restart count of the **topolvm-node** pod. An increased restart count indicates potential problems with the underlying node, which might require further investigation and troubleshooting.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to the OpenShift CLI (**oc**) as a user with **cluster-admin** permissions.

Procedure

- Examine the restart count of the **topolvm-node** pod instances by running the following command:

```
$ oc get pods -n openshift-storage
```

Example output

```
NAME                                READY   STATUS    RESTARTS      AGE
lvms-operator-7b9fb858cb-6nsml      3/3     Running   0             70m
topolvm-controller-5dd9cf78b5-7wwr2 5/5     Running   0             66m
topolvm-node-dr26h                  4/4     Running   0             66m
topolvm-node-54as8                  4/4     Running   0             66m
topolvm-node-78fft                  4/4     Running   17 (8s ago)   66m
vg-manager-r6zdv                    1/1     Running   0             66m
vg-manager-990ut                    1/1     Running   0             66m
vg-manager-an118                    1/1     Running   0             66m
```

Next steps

- If the PVC is stuck in the **Pending** state even after you have resolved any issues with the node, you must perform a forced clean-up. For more information, see "Performing a forced clean-up".

Additional resources

- Performing a forced clean-up

4.12.4.17.4. Recovering from disk failure

If you see a failure message while inspecting the events associated with the persistent volume claim (PVC), there can be a problem with the underlying volume or disk.

Disk and volume provisioning issues result with a generic error message such as **Failed to provision volume with storage class <storage_class_name>**. The generic error message is followed by a specific volume failure error message.

The following table describes the volume failure error messages:

Table 4.11. Volume failure error messages

Error message	Description
Failed to check volume existence	Indicates a problem in verifying whether the volume already exists. Volume verification failure can be caused by network connectivity problems or other failures.
Failed to bind volume	Failure to bind a volume can happen if the persistent volume (PV) that is available does not match the requirements of the PVC.
FailedMount or **FailedAttachVolume**	This error indicates problems when trying to mount the volume to a node. If the disk has failed, this error can appear when a pod tries to use the PVC.
FailedUnMount	This error indicates problems when trying to unmount a volume from a node. If the disk has failed, this error can appear when a pod tries to use the PVC.
Volume is already exclusively attached to one node and cannot be attached to another	This error can appear with storage solutions that do not support **ReadWriteMany** access modes.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to the OpenShift CLI (**oc**) as a user with **cluster-admin** permissions.

Procedure

1. Inspect the events associated with a PVC by running the following command:

```
$ oc describe pvc <pvc_name> 1
```

```
```

1 Replace **<pvc_name>** with the name of the PVC.

2. Establish a direct connection to the host where the problem is occurring.
3. Resolve the disk issue.

Next steps

- If the volume failure messages persist or recur even after you have resolved the issue with the disk, you must perform a forced clean-up. For more information, see "Performing a forced clean-up".

Additional resources

- Performing a forced clean-up

4.12.4.17.5. Performing a forced clean-up

If the disk or node-related problems persist even after you have completed the troubleshooting procedures, you must perform a forced clean-up. A forced clean-up is used to address persistent issues and ensure the proper functioning of Logical Volume Manager (LVM) Storage.

Prerequisites

- You have installed the OpenShift CLI (**oc**).
- You have logged in to the OpenShift CLI (**oc**) as a user with **cluster-admin** permissions.
- You have deleted all the persistent volume claims (PVCs) that were created by using LVM Storage.
- You have stopped the pods that are using the PVCs that were created by using LVM Storage.

Procedure

1. Switch to the **openshift-storage** namespace by running the following command:

```
$ oc project openshift-storage
```

2. Check if the **LogicalVolume** custom resources (CRs) are present by running the following command:

```
$ oc get logicalvolume
```

   a. If the **LogicalVolume** CRs are present, delete them by running the following command:

```
$ oc delete logicalvolume <name> 1
```

   1 Replace **<name>** with the name of the **LogicalVolume** CR.

   b. After deleting the **LogicalVolume** CRs, remove their finalizers by running the following command:

```
$ oc patch logicalvolume <name> -p '{"metadata":{"finalizers":[]}}' --type=merge 1
```

1 Replace **<name>** with the name of the **LogicalVolume** CR.

3. Check if the **LVMVolumeGroup** CRs are present by running the following command:

```
$ oc get lvmvolumegroup
```

   a. If the **LVMVolumeGroup** CRs are present, delete them by running the following command:

```
$ oc delete lvmvolumegroup <name> 1
```

   1 Replace **<name>** with the name of the **LVMVolumeGroup** CR.

   b. After deleting the **LVMVolumeGroup** CRs, remove their finalizers by running the following command:

```
$ oc patch lvmvolumegroup <name> -p '{"metadata":{"finalizers":[]}}' --type=merge 1
```

   1 Replace **<name>** with the name of the **LVMVolumeGroup** CR.

4. Delete any **LVMVolumeGroupNodeStatus** CRs by running the following command:

```
$ oc delete lvmvolumegroupnodestatus --all
```

5. Delete the **LVMCluster** CR by running the following command:

```
$ oc delete lvmcluster --all
```

   a. After deleting the **LVMCluster** CR, remove its finalizer by running the following command:

```
$ oc patch lvmcluster <name> -p '{"metadata":{"finalizers":[]}}' --type=merge 1
```

   1 Replace **<name>** with the name of the **LVMCluster** CR.

CHAPTER 5. USING CONTAINER STORAGE INTERFACE (CSI)

5.1. CONFIGURING CSI VOLUMES

The Container Storage Interface (CSI) allows OpenShift Container Platform to consume storage from storage back ends that implement the CSI interface as persistent storage.

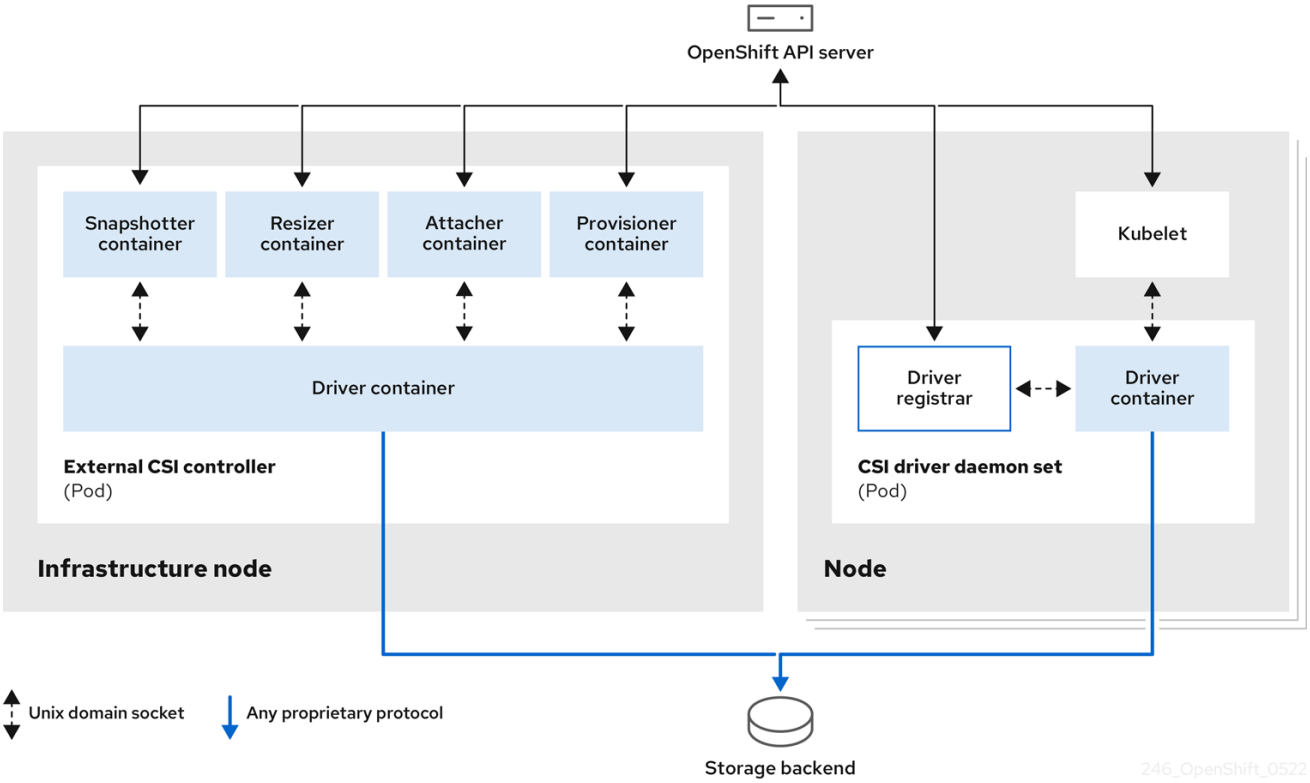
NOTE

OpenShift Container Platform 4.18 supports version 1.6.0 of the CSI specification.

5.1.1. CSI architecture

CSI drivers are typically shipped as container images. These containers are not aware of OpenShift Container Platform where they run. To use CSI-compatible storage back end in OpenShift Container Platform, the cluster administrator must deploy several components that serve as a bridge between OpenShift Container Platform and the storage driver.

The following diagram provides a high-level overview about the components running in pods in the OpenShift Container Platform cluster.



It is possible to run multiple CSI drivers for different storage back ends. Each driver needs its own external controllers deployment and daemon set with the driver and CSI registrar.

5.1.1.1. External CSI controllers

External CSI controllers is a deployment that deploys one or more pods with five containers:

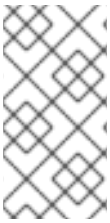
- The snapshotter container watches **VolumeSnapshot** and **VolumeSnapshotContent** objects and is responsible for the creation and deletion of **VolumeSnapshotContent** object.

- The resizer container is a sidecar container that watches for **PersistentVolumeClaim** updates and triggers **ControllerExpandVolume** operations against a CSI endpoint if you request more storage on **PersistentVolumeClaim** object.
- An external CSI attacher container translates **attach** and **detach** calls from OpenShift Container Platform to respective **ControllerPublish** and **ControllerUnpublish** calls to the CSI driver.
- An external CSI provisioner container that translates **provision** and **delete** calls from OpenShift Container Platform to respective **CreateVolume** and **DeleteVolume** calls to the CSI driver.
- A CSI driver container.

The CSI attacher and CSI provisioner containers communicate with the CSI driver container using UNIX Domain Sockets, ensuring that no CSI communication leaves the pod. The CSI driver is not accessible from outside of the pod.

NOTE

The **attach**, **detach**, **provision**, and **delete** operations typically require the CSI driver to use credentials to the storage backend. Run the CSI controller pods on infrastructure nodes so the credentials are never leaked to user processes, even in the event of a catastrophic security breach on a compute node.



NOTE

The external attacher must also run for CSI drivers that do not support third-party **attach** or **detach** operations. The external attacher will not issue any **ControllerPublish** or **ControllerUnpublish** operations to the CSI driver. However, it still must run to implement the necessary OpenShift Container Platform attachment API.

5.1.1.2. CSI driver daemon set

The CSI driver daemon set runs a pod on every node that allows OpenShift Container Platform to mount storage provided by the CSI driver to the node and use it in user workloads (pods) as persistent volumes (PVs). The pod with the CSI driver installed contains the following containers:

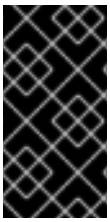
- A CSI driver registrar, which registers the CSI driver into the **openshift-node** service running on the node. The **openshift-node** process running on the node then directly connects with the CSI driver using the UNIX Domain Socket available on the node.
- A CSI driver.

The CSI driver deployed on the node should have as few credentials to the storage back end as possible. OpenShift Container Platform will only use the node plugin set of CSI calls such as **NodePublish**/**NodeUnpublish** and **NodeStage**/**NodeUnstage**, if these calls are implemented.

5.1.2. CSI drivers supported by OpenShift Container Platform

OpenShift Container Platform installs certain CSI drivers by default, giving users storage options that are not possible with in-tree volume plugins.

To create CSI-provisioned persistent volumes that mount to these supported storage assets, OpenShift Container Platform installs the necessary CSI driver Operator, the CSI driver, and the required storage class by default. For more details about the default namespace of the Operator and driver, see the documentation for the specific CSI Driver Operator.



IMPORTANT

The AWS EFS and GCP Filestore CSI drivers are not installed by default, and must be installed manually. For instructions on installing the AWS EFS CSI driver, see Setting up AWS Elastic File Service CSI Driver Operator. For instructions on installing the GCP Filestore CSI driver, see Google Compute Platform Filestore CSI Driver Operator .

The following table describes the CSI drivers that are installed with OpenShift Container Platform supported by OpenShift Container Platform and which CSI features they support, such as volume snapshots and resize.

IMPORTANT

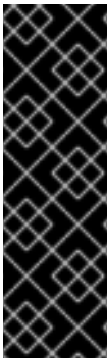
If your CSI driver is not listed in the following table, you must follow the installation instructions provided by your CSI storage vendor to use their supported CSI features.

Table 5.1. Supported CSI drivers and features in OpenShift Container Platform

CSI driver	CSI volume snapshots	CSI volume group snapshots [1]	CSI cloning	CSI resize	Inline ephemeral volumes
AWS EBS	▮			▮	
AWS EFS					
Google Compute Platform (GCP) persistent disk (PD)	▮		▮[2]	▮	
GCP Filestore	▮			▮	
IBM Power® Virtual Server Block				▮	
IBM Cloud® Block	▮[3]			▮[3]	
LVM Storage	▮		▮	▮	
Microsoft Azure Disk	▮		▮	▮	

CSI driver	CSI volume snapshots	CSI volume group snapshots [1]	CSI cloning	CSI resize	Inline ephemeral volumes
Microsoft Azure Stack Hub	▮		▮	▮	
Microsoft Azure File	▮[4]		▮[4]	▮	▮
OpenStack Cinder	▮		▮	▮	
OpenShift Data Foundation	▮	▮	▮	▮	
OpenStack Manila	▮			▮	
Shared Resource					▮
CIFS/SMB			▮		
VMware vSphere	▮[5]			▮[6]	

1.



IMPORTANT

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

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

2.

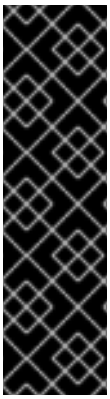
- Cloning is not supported on hyperdisk-balanced disks with storage pools.

3.

- Does not support offline snapshots or resize. Volume must be attached to a running pod.

4.

- Azure File cloning does not supports NFS protocol. It supports the **azurefile-csi** storage class, which uses SMB protocol.
- Azure File cloning and snapshot are Technology Preview features:



IMPORTANT

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

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

5.

- Requires vSphere version 7.0 Update 3 or later for both vCenter Server and ESXi.
- Does not support fileshare volumes.

6.

- Online expansion is supported from vSphere version 7.0 Update 2 and later.

5.1.3. Dynamic provisioning

Dynamic provisioning of persistent storage depends on the capabilities of the CSI driver and underlying storage back end. The provider of the CSI driver should document how to create a storage class in OpenShift Container Platform and the parameters available for configuration.

The created storage class can be configured to enable dynamic provisioning.

Procedure

- Create a default storage class that ensures all PVCs that do not require any special storage class are provisioned by the installed CSI driver.

```
# oc create -f - << EOF
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <storage-class> 1
  annotations:
    storageclass.kubernetes.io/is-default-class: "true"
provisioner: <provisioner-name> 2
parameters:
  csi.storage.k8s.io/fstype: xfs 3
EOF
```

1. The name of the storage class that will be created.
2. The name of the CSI driver that has been installed.
3. The vSphere CSI driver supports all of the file systems supported by the underlying Red Hat Core operating system release, including XFS and Ext4.

5.1.4. Example using the CSI driver

The following example installs a default MySQL template without any changes to the template.

Prerequisites

- The CSI driver has been deployed.
- A storage class has been created for dynamic provisioning.

Procedure

- Create the MySQL template:

```
# oc new-app mysql-persistent
```

Example output

```
--> Deploying template "openshift/mysql-persistent" to project default
...
```

```
# oc get pvc
```

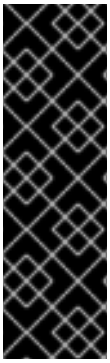
Example output

```
NAME             STATUS    VOLUME                                     CAPACITY
ACCESS MODES   STORAGECLASS   AGE
mysql            Bound     kubernetes-dynamic-pv-3271ffcb4e1811e8   1Gi
RWO            cinder        3s
```

5.1.5. Volume populators

Volume populators use the **datasource** field in a persistent volume claim (PVC) spec to create pre-populated volumes.

Volume population is currently enabled, and supported as a Technology Preview feature. However, OpenShift Container Platform does not ship with any volume populators.



IMPORTANT

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

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

For more information about volume populators, see Kubernetes volume populators .

5.2. CSI INLINE EPHEMERAL VOLUMES

Container Storage Interface (CSI) inline ephemeral volumes allow you to define a **Pod** spec that creates inline ephemeral volumes when a pod is deployed and delete them when a pod is destroyed.

This feature is only available with supported Container Storage Interface (CSI) drivers:

- Azure File CSI driver
- Secrets Store CSI driver

5.2.1. Overview of CSI inline ephemeral volumes

Traditionally, volumes that are backed by Container Storage Interface (CSI) drivers can only be used with a **PersistentVolume** and **PersistentVolumeClaim** object combination.

This feature allows you to specify CSI volumes directly in the **Pod** specification, rather than in a **PersistentVolume** object. Inline volumes are ephemeral and do not persist across pod restarts.

5.2.1.1. Support limitations

IMPORTANT

The Shared Resource CSI Driver feature is now generally available in Builds for Red Hat OpenShift 1.1. This feature is now removed in OpenShift Container Platform 4.18 and later. To use this feature, ensure that you are using Builds for Red Hat OpenShift 1.1 or later.

By default, OpenShift Container Platform supports CSI inline ephemeral volumes with these limitations:

- Support is only available for CSI drivers. In-tree and FlexVolumes are not supported.
- Community or storage vendors provide other CSI drivers that support these volumes. Follow the installation instructions provided by the CSI driver provider.

CSI drivers might not have implemented the inline volume functionality, including **Ephemeral** capacity. For details, see the CSI driver documentation.

5.2.2. CSI Volume Admission plugin

The Container Storage Interface (CSI) Volume Admission plugin allows you to restrict the use of an

individual CSI driver capable of provisioning CSI ephemeral volumes on pod admission. Administrators can add a **csi-ephemeral-volume-profile** label, and this label is then inspected by the Admission plugin and used in enforcement, warning, and audit decisions.

5.2.2.1. Overview

To use the CSI Volume Admission plugin, administrators add the **security.openshift.io/csi-ephemeral-volume-profile** label to a **CSIDriver** object, which declares the CSI driver's effective pod security profile when it is used to provide CSI ephemeral volumes, as shown in the following example:

```
kind: CSIDriver
metadata:
  name: csi.mydriver.company.org
  labels:
    security.openshift.io/csi-ephemeral-volume-profile: restricted (1)
```

(1) CSI driver object YAML file with the **csi-ephemeral-volume-profile** label set to "restricted"

This "effective profile" communicates that a pod can use the CSI driver to mount CSI ephemeral volumes when the pod's namespace is governed by a pod security standard.

The CSI Volume Admission plugin inspects pod volumes when pods are created; existing pods that use CSI volumes are not affected. If a pod uses a container storage interface (CSI) volume, the plugin looks up the **CSIDriver** object and inspects the **csi-ephemeral-volume-profile** label, and then use the label's value in its enforcement, warning, and audit decisions.

5.2.2.2. Pod security profile enforcement

When a CSI driver has the **csi-ephemeral-volume-profile** label, pods using the CSI driver to mount CSI ephemeral volumes must run in a namespace that enforces a pod security standard of equal or greater permission. If the namespace enforces a more restrictive standard, the CSI Volume Admission plugin denies admission. The following table describes the enforcement behavior for different pod security profiles for given label values.

Table 5.2. Pod security profile enforcement

Pod security profile	Driver label: restricted	Driver label: baseline	Driver label: privileged
Restricted	Allowed	Denied	Denied
Baseline	Allowed	Allowed	Denied
Privileged	Allowed	Allowed	Allowed

5.2.2.3. Pod security profile warning

The CSI Volume Admission plugin can warn you if the CSI driver's effective profile is more permissive than the pod security warning profile for the pod namespace. The following table shows when a warning occurs for different pod security profiles for given label values.

Table 5.3. Pod security profile warning

Pod security profile	Driver label: restricted	Driver label: baseline	Driver label: privileged
Restricted	No warning	Warning	Warning
Baseline	No warning	No warning	Warning
Privileged	No warning	No warning	No warning

5.2.2.4. Pod security profile audit

The CSI Volume Admission plugin can apply audit annotations to the pod if the CSI driver's effective profile is more permissive than the pod security audit profile for the pod namespace. The following table shows the audit annotation applied for different pod security profiles for given label values.

Table 5.4. Pod security profile audit

Pod security profile	Driver label: restricted	Driver label: baseline	Driver label: privileged
Restricted	No audit	Audit	Audit
Baseline	No audit	No audit	Audit
Privileged	No audit	No audit	No audit

5.2.2.5. Default behavior for the CSI Volume Admission plugin

If the referenced CSI driver for a CSI ephemeral volume does not have the **csi-ephemeral-volume-profile** label, the CSI Volume Admission plugin considers the driver to have the privileged profile for enforcement, warning, and audit behaviors. Likewise, if the pod's namespace does not have the pod security admission label set, the Admission plugin assumes the restricted profile is allowed for enforcement, warning, and audit decisions. Therefore, if no labels are set, CSI ephemeral volumes using that CSI driver are only usable in privileged namespaces by default.

The CSI drivers that ship with OpenShift Container Platform and support ephemeral volumes have a reasonable default set for the **csi-ephemeral-volume-profile** label:

- Azure File CSI driver: privileged

An admin can change the default value of the label if desired.

5.2.3. Embedding a CSI inline ephemeral volume in the pod specification

You can embed a CSI inline ephemeral volume in the **Pod** specification in OpenShift Container Platform. At runtime, nested inline volumes follow the ephemeral lifecycle of their associated pods so that the CSI driver handles all phases of volume operations as pods are created and destroyed.

Procedure

1. Create the **Pod** object definition and save it to a file.
2. Embed the CSI inline ephemeral volume in the file.

   my-csi-app.yaml

```
kind: Pod
apiVersion: v1
metadata:
  name: my-csi-app
spec:
  containers:
    - name: my-frontend
      image: busybox
      volumeMounts:
      - mountPath: "/data"
        name: my-csi-inline-vol
      command: [ "sleep", "1000000" ]
  volumes: 1
    - name: my-csi-inline-vol
      csi:
        driver: inline.storage.kubernetes.io
        volumeAttributes:
          foo: bar
```

   1 The name of the volume that is used by pods.

3. Create the object definition file that you saved in the previous step.

```
$ oc create -f my-csi-app.yaml
```

5.2.4. Additional resources

- Pod Security Standards

5.3. CSI VOLUME SNAPSHOTS

This document describes how to use volume snapshots with supported Container Storage Interface (CSI) drivers to help protect against data loss in OpenShift Container Platform. Familiarity with persistent volumes is suggested.

5.3.1. Overview of CSI volume snapshots

A *snapshot* represents the state of the storage volume in a cluster at a particular point in time. Volume snapshots can be used to provision a new volume.

OpenShift Container Platform supports Container Storage Interface (CSI) volume snapshots by default. However, a specific CSI driver is required.

With CSI volume snapshots, a cluster administrator can:

- Deploy a third-party CSI driver that supports snapshots.
- Create a new persistent volume claim (PVC) from an existing volume snapshot.
- Take a snapshot of an existing PVC.
- Restore a snapshot as a different PVC.
- Delete an existing volume snapshot.

With CSI volume snapshots, an app developer can:

- Use volume snapshots as building blocks for developing application- or cluster-level storage backup solutions.
- Rapidly rollback to a previous development version.
- Use storage more efficiently by not having to make a full copy each time.

Be aware of the following when using volume snapshots:

- Support is only available for CSI drivers. In-tree and FlexVolumes are not supported.
- OpenShift Container Platform only ships with select CSI drivers. For CSI drivers that are not provided by an OpenShift Container Platform Driver Operator, it is recommended to use the CSI drivers provided by community or storage vendors. Follow the installation instructions furnished by the CSI driver provider.
- CSI drivers may or may not have implemented the volume snapshot functionality. CSI drivers that have provided support for volume snapshots will likely use the **csi-external-snapshotter** sidecar. See documentation provided by the CSI driver for details.

5.3.2. CSI snapshot controller and sidecar

OpenShift Container Platform provides a snapshot controller that is deployed into the control plane. In addition, your CSI driver vendor provides the CSI snapshot sidecar as a helper container that is installed during the CSI driver installation.

The CSI snapshot controller and sidecar provide volume snapshotting through the OpenShift Container Platform API. These external components run in the cluster.

The external controller is deployed by the CSI Snapshot Controller Operator.

5.3.2.1. External controller

The CSI snapshot controller binds **VolumeSnapshot** and **VolumeSnapshotContent** objects. The controller manages dynamic provisioning by creating and deleting **VolumeSnapshotContent** objects.

5.3.2.2. External sidecar

Your CSI driver vendor provides the **csi-external-snapshotter** sidecar. This is a separate helper container that is deployed with the CSI driver. The sidecar manages snapshots by triggering **CreateSnapshot** and **DeleteSnapshot** operations. Follow the installation instructions provided by your vendor.

5.3.3. About the CSI Snapshot Controller Operator

The CSI Snapshot Controller Operator runs in the **openshift-cluster-storage-operator** namespace. It is installed by the Cluster Version Operator (CVO) in all clusters by default.

The CSI Snapshot Controller Operator installs the CSI snapshot controller, which runs in the **openshift-cluster-storage-operator** namespace.

5.3.3.1. Volume snapshot CRDs

During OpenShift Container Platform installation, the CSI Snapshot Controller Operator creates the following snapshot custom resource definitions (CRDs) in the **snapshot.storage.k8s.io/v1** API group:

VolumeSnapshotContent

A snapshot taken of a volume in the cluster that has been provisioned by a cluster administrator. Similar to the **PersistentVolume** object, the **VolumeSnapshotContent** CRD is a cluster resource that points to a real snapshot in the storage back end.

For manually pre-provisioned snapshots, a cluster administrator creates a number of **VolumeSnapshotContent** CRDs. These carry the details of the real volume snapshot in the storage system.

The **VolumeSnapshotContent** CRD is not namespaced and is for use by a cluster administrator.

VolumeSnapshot

Similar to the **PersistentVolumeClaim** object, the **VolumeSnapshot** CRD defines a developer request for a snapshot. The CSI Snapshot Controller Operator runs the CSI snapshot controller, which handles the binding of a **VolumeSnapshot** CRD with an appropriate **VolumeSnapshotContent** CRD. The binding is a one-to-one mapping.
The **VolumeSnapshot** CRD is namespaced. A developer uses the CRD as a distinct request for a snapshot.

VolumeSnapshotClass

Allows a cluster administrator to specify different attributes belonging to a **VolumeSnapshot** object. These attributes may differ among snapshots taken of the same volume on the storage system, in which case they would not be expressed by using the same storage class of a persistent volume claim.
The **VolumeSnapshotClass** CRD defines the parameters for the **csi-external-snapshotter** sidecar to use when creating a snapshot. This allows the storage back end to know what kind of snapshot to dynamically create if multiple options are supported.

Dynamically provisioned snapshots use the **VolumeSnapshotClass** CRD to specify storage-provider-specific parameters to use when creating a snapshot.

The **VolumeSnapshotContentClass** CRD is not namespaced and is for use by a cluster administrator to enable global configuration options for their storage back end.

5.3.4. Volume snapshot provisioning

There are two ways to provision snapshots: dynamically and manually.

5.3.4.1. Dynamic provisioning

Instead of using a preexisting snapshot, you can request that a snapshot be taken dynamically from a persistent volume claim. Parameters are specified using a **VolumeSnapshotClass** CRD.

5.3.4.2. Manual provisioning

As a cluster administrator, you can manually pre-provision a number of **VolumeSnapshotContent** objects. These carry the real volume snapshot details available to cluster users.

5.3.5. Creating a volume snapshot

When you create a **VolumeSnapshot** object, OpenShift Container Platform creates a volume snapshot.

Prerequisites

- Logged in to a running OpenShift Container Platform cluster.
- A PVC created using a CSI driver that supports **VolumeSnapshot** objects.
- A storage class to provision the storage back end.
- No pods are using the persistent volume claim (PVC) that you want to take a snapshot of.

WARNING

Creating a volume snapshot of a PVC that is in use by a pod can cause unwritten data and cached data to be excluded from the snapshot. To ensure that all data is written to the disk, delete the pod that is using the PVC before creating the snapshot.

Procedure

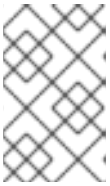
To dynamically create a volume snapshot:

1. Create a file with the **VolumeSnapshotClass** object described by the following YAML:

   volumesnapshotclass.yaml

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshotClass
metadata:
  name: csi-hostpath-snap
driver: hostpath.csi.k8s.io (1)
deletionPolicy: Delete
```

(1) The name of the CSI driver that is used to create snapshots of this **VolumeSnapshotClass** object. The name must be the same as the **Provisioner** field of the storage class that is responsible for the PVC that is being snapshotted.



NOTE

Depending on the driver that you used to configure persistent storage, additional parameters might be required. You can also use an existing **VolumeSnapshotClass** object.

2. Create the object you saved in the previous step by entering the following command:

```
$ oc create -f volumesnapshotclass.yaml
```

3. Create a **VolumeSnapshot** object:

volumesnapshot-dynamic.yaml

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
  name: mysnap
spec:
  volumeSnapshotClassName: csi-hostpath-snap (1)
  source:
    persistentVolumeClaimName: myclaim (2)
```

(1) The request for a particular class by the volume snapshot. If the **volumeSnapshotClassName** setting is absent and there is a default volume snapshot class, a snapshot is created with the default volume snapshot class name. But if the field is absent and no default volume snapshot class exists, then no snapshot is created.

(2) The name of the **PersistentVolumeClaim** object bound to a persistent volume. This defines what you want to create a snapshot of. Required for dynamically provisioning a snapshot.

4. Create the object you saved in the previous step by entering the following command:

```
$ oc create -f volumesnapshot-dynamic.yaml
```

To manually provision a snapshot:

1. Provide a value for the **volumeSnapshotContentName** parameter as the source for the snapshot, in addition to defining volume snapshot class as shown above.

volumesnapshot-manual.yaml

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
  name: snapshot-demo
spec:
  source:
    volumeSnapshotContentName: mycontent (1)
```

(1) The **volumeSnapshotContentName** parameter is required for pre-provisioned snapshots.

2. Create the object you saved in the previous step by entering the following command:

```
$ oc create -f volumesnapshot-manual.yaml
```

Verification

After the snapshot has been created in the cluster, additional details about the snapshot are available.

1. To display details about the volume snapshot that was created, enter the following command:

```
$ oc describe volumesnapshot mysnap
```

The following example displays details about the **mysnap** volume snapshot:

volumesnapshot.yaml

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
  name: mysnap
spec:
  source:
    persistentVolumeClaimName: myclaim
  volumeSnapshotClassName: csi-hostpath-snap
status:
  boundVolumeSnapshotContentName: snapcontent-1af4989e-a365-4286-96f8-
d5dcd65d78d6 (1)
  creationTime: "2020-01-29T12:24:30Z" (2)
  readyToUse: true (3)
  restoreSize: 500Mi
```

(1) The pointer to the actual storage content that was created by the controller.

(2) The time when the snapshot was created. The snapshot contains the volume content that was available at this indicated time.

(3) If the value is set to **true**, the snapshot can be used to restore as a new PVC.
If the value is set to **false**, the snapshot was created. However, the storage back end needs to perform additional tasks to make the snapshot usable so that it can be restored as a new volume. For example, Amazon Elastic Block Store data might be moved to a different, less expensive location, which can take several minutes.

2. To verify that the volume snapshot was created, enter the following command:

```
$ oc get volumesnapshotcontent
```

The pointer to the actual content is displayed. If the **boundVolumeSnapshotContentName** field is populated, a **VolumeSnapshotContent** object exists and the snapshot was created.

3. To verify that the snapshot is ready, confirm that the **VolumeSnapshot** object has **readyToUse: true**.

5.3.6. Deleting a volume snapshot

You can configure how OpenShift Container Platform deletes volume snapshots.

Procedure

1. Specify the deletion policy that you require in the **VolumeSnapshotClass** object, as shown in the following example:

   volumesnapshotclass.yaml

   ```
   apiVersion: snapshot.storage.k8s.io/v1
   kind: VolumeSnapshotClass
   metadata:
     name: csi-hostpath-snap
   driver: hostpath.csi.k8s.io
   deletionPolicy: Delete (1)
   ```

   (1) When deleting the volume snapshot, if the **Delete** value is set, the underlying snapshot is deleted along with the **VolumeSnapshotContent** object. If the **Retain** value is set, both the underlying snapshot and **VolumeSnapshotContent** object remain.
   If the **Retain** value is set and the **VolumeSnapshot** object is deleted without deleting the corresponding **VolumeSnapshotContent** object, the content remains. The snapshot itself is also retained in the storage back end.

2. Delete the volume snapshot by entering the following command:

   ```
   $ oc delete volumesnapshot <volumesnapshot_name> (1)
   ```

   (1) Replace *<volumesnapshot_name>* with the name of the volume snapshot you want to delete.

   Example output

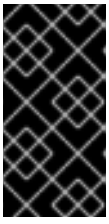
   ```
   volumesnapshot.snapshot.storage.k8s.io "mysnapshot" deleted
   ```

3. If the deletion policy is set to **Retain**, delete the volume snapshot content by entering the following command:

   ```
   $ oc delete volumesnapshotcontent <volumesnapshotcontent_name> (1)
   ```

   (1) Replace *<volumesnapshotcontent_name>* with the content you want to delete.

4. Optional: If the **VolumeSnapshot** object is not successfully deleted, enter the following command to remove any finalizers for the leftover resource so that the delete operation can continue:

   IMPORTANT

   Only remove the finalizers if you are confident that there are no existing references from either persistent volume claims or volume snapshot contents to the **VolumeSnapshot** object. Even with the **--force** option, the delete operation does not delete snapshot objects until all finalizers are removed.

```
$ oc patch -n $PROJECT volumesnapshot/$NAME --type=merge -p '{"metadata":
{"finalizers":null}}'
```

Example output

```
volumesnapshotclass.snapshot.storage.k8s.io "csi-ocs-rbd-snapclass" deleted
```

The finalizers are removed and the volume snapshot is deleted.

5.3.7. Restoring a volume snapshot

The **VolumeSnapshot** CRD content can be used to restore the existing volume to a previous state.

After your **VolumeSnapshot** CRD is bound and the **readyToUse** value is set to **true**, you can use that resource to provision a new volume that is pre-populated with data from the snapshot.

Prerequisites

- Logged in to a running OpenShift Container Platform cluster.
- A persistent volume claim (PVC) created using a Container Storage Interface (CSI) driver that supports volume snapshots.
- A storage class to provision the storage back end.
- A volume snapshot has been created and is ready to use.

Procedure

1. Specify a **VolumeSnapshot** data source on a PVC as shown in the following:

   pvc-restore.yaml

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: myclaim-restore
spec:
  storageClassName: csi-hostpath-sc
  dataSource:
    name: mysnap 1
    kind: VolumeSnapshot 2
    apiGroup: snapshot.storage.k8s.io 3
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
```

1. Name of the **VolumeSnapshot** object representing the snapshot to use as source.
2. Must be set to the **VolumeSnapshot** value.

3 Must be set to the **snapshot.storage.k8s.io** value.

2. Create a PVC by entering the following command:

```
$ oc create -f pvc-restore.yaml
```

3. Verify that the restored PVC has been created by entering the following command:

```
$ oc get pvc
```

A new PVC such as **myclaim-restore** is displayed.

5.3.8. Changing the maximum number of snapshots for vSphere

The default maximum number of snapshots per volume in vSphere Container Storage Interface (CSI) is 3. You can change the maximum number up to 32 per volume.

However, be aware that increasing the snapshot maximum involves a performance trade off, so for better performance use only 2 to 3 snapshots per volume.

For more VMware snapshot performance recommendations, see ***Additional resources***.

Prerequisites

- Access to the cluster with administrator rights.

Procedure

1. Check the current secret by the running the following command:

```
$ oc -n openshift-cluster-csi-drivers get secret/vsphere-csi-config-secret -o
jsonpath='{.data.cloud\.conf}' | base64 -d
```

Example output

```
# Labels with topology values are added dynamically via operator
[Global]
cluster-id = vsphere-01-cwv8p

# Populate VCenters (multi) after here
[VirtualCenter "vcenter.openshift.com"]
insecure-flag        = true
datacenters          = DEVQEdatacenter
password             = "xxxxxxxx"
user                 = "xxxxxxxx@devcluster.openshift.com"
migration-datastore-url = ds:///vmfs/volumes/vsan:52c842f232751e0d-3253aadeac21ca82/
```

In this example, the global maximum number of snapshots is not configured, so the default value of 3 is applied.

2. Change the snapshot limit by running the following command:

- Set **global** snapshot limit:

```
$ oc patch clustercsidriver/csi.vsphere.vmware.com --type=merge -p '{"spec":
{"driverConfig":{"vSphere":{"globalMaxSnapshotsPerBlockVolume": 10}}}}'

clustercsidriver.operator.openshift.io/csi.vsphere.vmware.com patched
```

In this example, the global limit is being changed to 10 (**globalMaxSnapshotsPerBlockVolume** set to 10).

- Set **Virtual Volume** snapshot limit:
  This parameter sets the limit on the Virtual Volumes datastore only. The Virtual Volume maximum snapshot limit overrides the global constraint if set, but defaults to the global limit if it is not set.

```
$ oc patch clustercsidriver/csi.vsphere.vmware.com --type=merge -p '{"spec":
{"driverConfig":{"vSphere":{"granularMaxSnapshotsPerBlockVolumeInVVOL": 5}}}}'
clustercsidriver.operator.openshift.io/csi.vsphere.vmware.com patched
```

In this example, the Virtual Volume limit is being changed to 5 (**granularMaxSnapshotsPerBlockVolumeInVVOL** set to 5).

- Set **vSAN** snapshot limit:
  This parameter sets the limit on the vSAN datastore only. The vSAN maximum snapshot limit overrides the global constraint if set, but defaults to the global limit if it is not set. You can set a maximum value of 32 under vSAN ESA setup.

```
$ oc patch clustercsidriver/csi.vsphere.vmware.com --type=merge -p '{"spec":
{"driverConfig":{"vSphere":{"granularMaxSnapshotsPerBlockVolumeInVSAN": 7}}}}'
clustercsidriver.operator.openshift.io/csi.vsphere.vmware.com patched
```

In this example, the vSAN limit is being changed to 7 (**granularMaxSnapshotsPerBlockVolumeInVSAN** set to 7).

Verification

- Verify that any changes you made are reflected in the config map by running the following command:

```
$ oc -n openshift-cluster-csi-drivers get secret/vsphere-csi-config-secret -o
jsonpath='{.data.cloud\.conf}' | base64 -d
```

Example output

```
# Labels with topology values are added dynamically via operator
[Global]
cluster-id = vsphere-01-cwv8p

# Populate VCenters (multi) after here
[VirtualCenter "vcenter.openshift.com"]
insecure-flag           = true
datacenters             = DEVQEdatacenter
password                = "xxxxxxxx"
user                  = "xxxxxxxx@devcluster.openshift.com"
migration-datastore-url = ds:///vmfs/volumes/vsan:52c842f232751e0d-3253aadeac21ca82/
```

```
[Snapshot]
global-max-snapshots-per-block-volume = 10 (1)
```

(1) **global-max-snapshots-per-block-volume** is now set to 10.

5.3.9. Additional resources

- Best practices for using VMware snapshots in the vSphere environment

5.4. CSI VOLUME GROUP SNAPSHOTS

This document describes how to use volume group snapshots with supported Container Storage Interface (CSI) drivers to help protect against data loss in OpenShift Container Platform. Familiarity with persistent volumes is suggested.

IMPORTANT

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

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

To use this Technology Preview feature, you must enable it using feature gates .

5.4.1. Overview of CSI volume group snapshots

A *snapshot* represents the state of the storage volume in a cluster at a particular point in time. Volume snapshots can be used to provision a new volume.

A *volume group snapshot* uses a label selector to group multiple persistent volume claims for snapshotting. A volume group snapshot represents copies from multiple volumes that are taken at the same point-in-time. This can be useful for applications that contain multiple volumes.

Container Storage Interface (CSI) volume group snapshots needs to be supported by the CSI driver. OpenShift Data Foundation supports volume group snapshots.

Volume group snapshots provide three new API objects for managing snapshots:

VolumeGroupSnapshot

Requests creation of a volume group snapshot for multiple persistent volume claims. It contains information about the volume group snapshot operation, such as the timestamp when the volume group snapshot was taken, and whether it is ready to use.

VolumeGroupSnapshotContent

Created by the snapshot controller for a dynamically created volumeGroupSnapshot. It contains information about the volume group snapshot including the volume group snapshot ID. This object represents a provisioned resource on the cluster (a group snapshot). The

VolumeGroupSnapshotContent object binds to the volume group snapshot for which it was created with a one-to-one mapping.

VolumeGroupSnapshotClass

Created by cluster administrators to describe how volume group snapshots should be created, including the driver information, the deletion policy, etc.

These three API kinds are defined as **CustomResourceDefinitions** (CRDs). These CRDs must be installed in a OpenShift Container Platform cluster for a CSI driver to support volume group snapshots.

5.4.2. CSI volume group snapshots limitations

Volume group snapshots has the following limitations:

- Does not support reverting an existing persistent volume claim (PVC) to an earlier state represented by a snapshot It only supports provisioning a new volume from a snapshot.
- No guarantees of application consistency, for example, crash consistency, are provided beyond those provided by the storage system. For more information about application consistency, see Quiesce and Unquiesce Hooks.

5.4.3. Creating a volume group snapshot class

Before you can create volume group snapshots, the cluster administrator needs to create a **VolumeGroupSnapshotClass**.

This object describes how volume group snapshots should be created, including the driver information, the deletion policy, etc.

Prerequisites

- Logged in to a running OpenShift Container Platform cluster with administrator privileges.
- Enabled this feature using feature gates. For information about how to use feature gates, see *Enabling features sets by using feature gates* .

Procedure

To create a **VolumeGroupSnapshotClass**:

1. Create a **VolumeGroupSnapshotClass** YAML file using the following example file:

Example volume group snapshot class YAML file

```
apiVersion: groupsnapshot.storage.k8s.io/v1beta1
kind: VolumeGroupSnapshotClass 1
metadata:
  name: csi-hostpath-groupsnapclass 2
deletionPolicy: Delete
driver: hostpath.csi.k8s.io
    .....
```

1. Specifies the **VolumeGroupSnapshotClass** object.
2. Name of the **VolumeGroupSnapshotClass**.

2. Create the 'VolumeGroupSnapshotClass' object by running the following command:

```
$ oc create -f <volume-group-snapshot-class-filename>.yaml
```

5.4.4. Creating a volume group snapshot

When you create a **VolumeGroupSnapshot** object, OpenShift Container Platform creates a volume group snapshot.

Prerequisites

- Logged in to a running OpenShift Container Platform cluster.
- Enabled this feature using feature gates. For information about how to use feature gates, see *Enabling features sets by using feature gates* .
- The persistent volume claims (PVCs) that you want to group for the snapshot have been created using a CSI driver that supports **VolumeGroupSnapshot** objects.
- A storage class to provision the storage back end.
- Administrator has created the **VolumeGroupSnapshotClass** object.

Procedure

To create a volume group snapshot:

1. Locate (or create) the PVCs that you want to include in the volume group snapshot:

```
$ oc get pvc
```

Example command output

```
NAME      STATUS   VOLUME                                     CAPACITY   ACCESSMODES   AGE
pvc-0     Bound    pvc-a42d7ea2-e3df-11ed-b5ea-0242ac120002   1Gi        RWO           48s
pvc-1     Bound    pvc-a42d81b8-e3df-11ed-b5ea-0242ac120002   1Gi        RWO           48S
```

This example uses two PVCs

2. Label the PVCs to belong to a snapshot group:

   a. Label PVC pvc-0 by running the following command:

```
$ oc label pvc pvc-0 group=myGroup
```

Example output

```
persistentvolumeclaim/pvc-0 labeled
```

   b. Label PVC pvc-1 by running the following command:

```
$ oc label pvc pvc-1 group=myGroup
```

Example output

```
persistentvolumeclaim/pvc-1 labeled
```

In this example, you are labeling PVC "pvc-0" and "pvc-1" to belong to group "myGroup".

3. Create a **VolumeGroupSnapshot** object to specify your volume group snapshot:

   a. Create a **VolumeGroupSnapshot** object YAML file with the following example file:

Example VolumeGroupSnapshot YAML file

```
apiVersion: groupsnapshot.storage.k8s.io/v1beta1
kind: VolumeGroupSnapshot (1)
metadata:
  name: <volume-group-snapshot-name> (2)
  namespace: <namespace> (3)
spec:
  volumeGroupSnapshotClassName: <volume-group-snapshot-class-name> (4)
  source:
    selector:
      matchLabels:
        group: myGroup (5)
```

(1) The **VolumeGroupSnapshot** object requests creation of a volume group snapshot for multiple PVCs.

(2) Name of the volume group snapshot.

(3) Namespace for the volume group snapshot.

(4) The **VolumeGroupSnapshotClass** name. This object is created by the administrator and describes how volume group snapshots should be created.

(5) The name of the label used to group the desired PVCs for the snapshot. In this example, it is "myGroup".

   b. Create the **VolumeGroupSnapshot** object by running the following command:

```
$ oc create -f <volume-group-snapshot-filename>.yaml
```

Results

Individual volume snapshots are created according to how many PVCs were specified as part of the volume group snapshot.

These individual volume snapshots are named with the following format: <hash of VolumeGroupSnaphotContentUUID+volumeHandle>:

Example individual volume snapshot

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
```

```
  name: snapshot-4dc1c53a29538b36e85003503a4bcac5dbde4cff59e81f1e3bb80b6c18c3fd03
  namespace: default
  ownerReferences:
  - apiVersion: groupsnapshot.storage.k8s.io/v1beta1
    kind: VolumeGroupSnapshot
    name: my-groupsnapshot
    uid: ba2d60c5-5082-4279-80c2-daa85f0af354
  resourceVersion: "124503"
  uid: c0137282-f161-4e86-92c1-c41d36c6d04c
spec:
  source:
    persistentVolumeClaimName:pvc-1
status:
  volumeGroupSnapshotName: volume-group-snapshot-name
```

In the preceding example, two individual volume snapshots are created as part of the volume group snapshot.

```
snapshot-4dc1c53a29538b36e85003503a4bcac5dbde4cff59e81f1e3bb80b6c18c3fd03
snapshot-fbfe59eff570171765df664280910c3bf1a4d56e233a5364cd8cb0152a35965b
```

5.4.5. Restoring a volume group snapshot

You can use the **VolumeGroupSnapshot** custom resource definition (CRD) content to restore the existing volumes to a previous state.

To restore existing volumes, you can request a new persistent volume claim (PVC) to be created from a **VolumeSnapshot** object that is part of a **VolumeGroupSnapshot**. This triggers provisioning of a new volume that is populated with data from the specified snapshot. Repeat this process until all volumes are created from all the snapshots that are part of a volume group snapshot.

Prerequisites

- Logged in to a running OpenShift Container Platform cluster.
- PVC has been created using a Container Storage Interface (CSI) driver that supports volume group snapshots.
- A storage class to provision the storage back end.
- A volume group snapshot has been created and is ready to use.

Procedure

To restore existing volumes to a previous state from a volume group snapshot:

1. Specify a **VolumeSnapshot** data source from a volume group snapshot for a PVC as shown in the following example:

   Example restore PVC YAML file

   ```
   apiVersion: v1
   kind: PersistentVolumeClaim
   metadata:
     name: <pvc-restore-name> 1
   ```

```
  namespace: <namespace> 2
spec:
  storageClassName: csi-hostpath-sc
  dataSource:
    name: snapshot-
fbfe59eff570171765df664280910c3bf1a4d56e233a5364cd8cb0152a35965b 3
    kind: VolumeSnapshot 4
    apiGroup: snapshot.storage.k8s.io 5
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
```

1. Name of the restore PVC.
2. Name of the namespace.
3. Name of an individual volume snapshot that is part of the volume group snapshot to use as source.
4. Must be set to the **VolumeSnapshot** value.
5. Must be set to the **snapshot.storage.k8s.io** value

2. Create the PVC by running the following command:

```
$ oc create -f <pvc-restore-filename>.yaml 1
```

1. Name of the PVC restore file specified in the preceding step.

3. Verify that the restored PVC has been created by running the following command:

```
$ oc get pvc
```

A new PVC with the name you specified in the first step appears.

4. Repeat the procedure as needed until all volumes are created from all the snapshots that are part of a volume group snapshot.

5.4.6. Additional resources

- CSI volume snapshots
- Enabling features sets by using feature gates

5.5. CSI VOLUME CLONING

Volume cloning duplicates an existing persistent volume to help protect against data loss in OpenShift Container Platform. This feature is only available with supported Container Storage Interface (CSI) drivers. You should be familiar with persistent volumes before you provision a CSI volume clone.

5.5.1. Overview of CSI volume cloning

A Container Storage Interface (CSI) volume clone is a duplicate of an existing persistent volume at a particular point in time.

Volume cloning is similar to volume snapshots, although it is more efficient. For example, a cluster administrator can duplicate a cluster volume by creating another instance of the existing cluster volume.

Cloning creates an exact duplicate of the specified volume on the back-end device, rather than creating a new empty volume. After dynamic provisioning, you can use a volume clone just as you would use any standard volume.

No new API objects are required for cloning. The existing **dataSource** field in the **PersistentVolumeClaim** object is expanded so that it can accept the name of an existing PersistentVolumeClaim in the same namespace.

5.5.1.1. Support limitations

By default, OpenShift Container Platform supports CSI volume cloning with these limitations:

- The destination persistent volume claim (PVC) must exist in the same namespace as the source PVC.
- Cloning is supported with a different Storage Class.
  - Destination volume can be the same for a different storage class as the source.
  - You can use the default storage class and omit **storageClassName** in the **spec**.
- Support is only available for CSI drivers. In-tree and FlexVolumes are not supported.
- CSI drivers might not have implemented the volume cloning functionality. For details, see the CSI driver documentation.

5.5.2. Provisioning a CSI volume clone

When you create a cloned persistent volume claim (PVC) API object, you trigger the provisioning of a CSI volume clone. The clone pre-populates with the contents of another PVC, adhering to the same rules as any other persistent volume. The one exception is that you must add a **dataSource** that references an existing PVC in the same namespace.

Prerequisites

- You are logged in to a running OpenShift Container Platform cluster.
- Your PVC is created using a CSI driver that supports volume cloning.
- Your storage back end is configured for dynamic provisioning. Cloning support is not available for static provisioners.

Procedure

To clone a PVC from an existing PVC:

1. Create and save a file with the **PersistentVolumeClaim** object described by the following YAML:

pvc-clone.yaml

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc-1-clone
  namespace: mynamespace
spec:
  storageClassName: csi-cloning 1
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 5Gi
  dataSource:
    kind: PersistentVolumeClaim
    name: pvc-1
```

1 The name of the storage class that provisions the storage back end. The default storage class can be used and **storageClassName** can be omitted in the spec.

2. Create the object you saved in the previous step by running the following command:

```
$ oc create -f pvc-clone.yaml
```

A new PVC **pvc-1-clone** is created.

3. Verify that the volume clone was created and is ready by running the following command:

```
$ oc get pvc pvc-1-clone
```

The **pvc-1-clone** shows that it is **Bound**.

You are now ready to use the newly cloned PVC to configure a pod.

4. Create and save a file with the **Pod** object described by the YAML. For example:

```
kind: Pod
apiVersion: v1
metadata:
  name: mypod
spec:
  containers:
    - name: myfrontend
      image: dockerfile/nginx
      volumeMounts:
      - mountPath: "/var/www/html"
        name: mypd
  volumes:
    - name: mypd
      persistentVolumeClaim:
        claimName: pvc-1-clone 1
```

1 The cloned PVC created during the CSI volume cloning operation.

The created **Pod** object is now ready to consume, clone, snapshot, or delete your cloned PVC independently of its original **dataSource** PVC.

5.6. MANAGING THE DEFAULT STORAGE CLASS

5.6.1. Overview

Managing the default storage class allows you to accomplish several different objectives:

- Enforcing static provisioning by disabling dynamic provisioning.
- When you have other preferred storage classes, preventing the storage operator from re-creating the initial default storage class.
- Renaming, or otherwise changing, the default storage class

To accomplish these objectives, you change the setting for the **spec.storageClassState** field in the **ClusterCSIDriver** object. The possible settings for this field are:

- **Managed**: (Default) The Container Storage Interface (CSI) operator is actively managing its default storage class, so that most manual changes made by a cluster administrator to the default storage class are removed, and the default storage class is continuously re-created if you attempt to manually delete it.
- **Unmanaged**: You can modify the default storage class. The CSI operator is not actively managing storage classes, so that it is not reconciling the default storage class it creates automatically.
- **Removed**: The CSI operators deletes the default storage class.

Managing the default storage classes is supported by the following Container Storage Interface (CSI) driver operators:

- Amazon Web Services (AWS) Elastic Block Storage (EBS)
- Azure Disk
- Azure File
- Google Cloud Platform (GCP) Persistent Disk (PD)
- IBM Cloud® VPC Block
- OpenStack Cinder
- VMware vSphere

5.6.2. Managing the default storage class using the web console

Prerequisites

- Access to the OpenShift Container Platform web console.
- Access to the cluster with cluster-admin privileges.

Procedure

To manage the default storage class using the web console:

1. Log in to the web console.
2. Click **Administration** > **CustomResourceDefinitions**.
3. On the **CustomResourceDefinitions** page, type **clustercsidriver** to find the **ClusterCSIDriver** object.
4. Click **ClusterCSIDriver**, and then click the **Instances** tab.
5. Click the name of the desired instance, and then click the **YAML** tab.
6. Add the **spec.storageClassState** field with a value of **Managed**, **Unmanaged**, or **Removed**.

   Example

```
...
spec:
  driverConfig:
    driverType: ''
  logLevel: Normal
  managementState: Managed
  observedConfig: null
  operatorLogLevel: Normal
  storageClassState: Unmanaged (1)
...
```

   (1) **spec.storageClassState** field set to "Unmanaged"

7. Click **Save**.

5.6.3. Managing the default storage class using the CLI

Prerequisites

- Access to the cluster with cluster-admin privileges.

Procedure

To manage the storage class using the CLI, run the following command:

```
oc patch clustercsidriver $DRIVERNAME --type=merge -p "{\"spec\":
{\"storageClassState\":\"${STATE}\"}}" (1)
```

(1) Where **${STATE}** is "Removed" or "Managed" or "Unmanaged".

Where **$DRIVERNAME** is the provisioner name. You can find the provisioner name by running the command **oc get sc**.

5.6.4. Absent or multiple default storage classes

5.6.4.1. Multiple default storage classes

Multiple default storage classes can occur if you mark a non-default storage class as default and do not unset the existing default storage class, or you create a default storage class when a default storage class is already present. With multiple default storage classes present, any persistent volume claim (PVC) requesting the default storage class (**pvc.spec.storageClassName**=nil) gets the most recently created default storage class, regardless of the default status of that storage class, and the administrator receives an alert in the alerts dashboard that there are multiple default storage classes, **MultipleDefaultStorageClasses**.

5.6.4.2. Absent default storage class

There are two possible scenarios where PVCs can attempt to use a non-existent default storage class:

- An administrator removes the default storage class or marks it as non-default, and then a user creates a PVC requesting the default storage class.
- During installation, the installer creates a PVC requesting the default storage class, which has not yet been created.

In the preceding scenarios, PVCs remain in the pending state indefinitely. To resolve this situation, create a default storage class or declare one of the existing storage classes as the default. As soon as the default storage class is created or declared, the PVCs get the new default storage class. If possible, the PVCs eventually bind to statically or dynamically provisioned PVs as usual, and move out of the pending state.

5.6.5. Changing the default storage class

Use the following procedure to change the default storage class.

For example, if you have two defined storage classes, **gp3** and **standard**, and you want to change the default storage class from **gp3** to **standard**.

Prerequisites

- Access to the cluster with cluster-admin privileges.

Procedure

To change the default storage class:

1. List the storage classes:

```
$ oc get storageclass
```

Example output

```
NAME            TYPE
gp3 (default)    kubernetes.io/aws-ebs (1)
standard        kubernetes.io/aws-ebs
```

(1) **(default)** indicates the default storage class.

2. Make the desired storage class the default.

For the desired storage class, set the **storageclass.kubernetes.io/is-default-class** annotation to **true** by running the following command:

```
$ oc patch storageclass standard -p '{"metadata": {"annotations":
{"storageclass.kubernetes.io/is-default-class": "true"}}}'
```

NOTE

You can have multiple default storage classes for a short time. However, you should ensure that only one default storage class exists eventually.

With multiple default storage classes present, any persistent volume claim (PVC) requesting the default storage class (**pvc.spec.storageClassName**=nil) gets the most recently created default storage class, regardless of the default status of that storage class, and the administrator receives an alert in the alerts dashboard that there are multiple default storage classes, **MultipleDefaultStorageClasses**.

3. Remove the default storage class setting from the old default storage class.
For the old default storage class, change the value of the **storageclass.kubernetes.io/is-default-class** annotation to **false** by running the following command:

```
$ oc patch storageclass gp3 -p '{"metadata": {"annotations": {"storageclass.kubernetes.io/is-
default-class": "false"}}}'
```

4. Verify the changes:

```
$ oc get storageclass
```

Example output

```
NAME                TYPE
gp3                 kubernetes.io/aws-ebs
standard (default)  kubernetes.io/aws-ebs
```

5.7. CSI AUTOMATIC MIGRATION

In-tree storage drivers that are traditionally shipped with OpenShift Container Platform are being deprecated and replaced by their equivalent Container Storage Interface (CSI) drivers. OpenShift Container Platform provides automatic migration for in-tree volume plugins to their equivalent CSI drivers.

5.7.1. Overview

This feature automatically migrates volumes that were provisioned using in-tree storage plugins to their counterpart Container Storage Interface (CSI) drivers.

This process does not perform any data migration; OpenShift Container Platform only translates the persistent volume object in memory. As a result, the translated persistent volume object is not stored on disk, nor is its contents changed. CSI automatic migration should be seamless. This feature does not change how you use all existing API objects: for example, **PersistentVolumes**, **PersistentVolumeClaims**, and **StorageClasses**.

The following in-tree to CSI drivers are automatically migrated:

- Azure Disk
- OpenStack Cinder
- Amazon Web Services (AWS) Elastic Block Storage (EBS)
- Google Compute Engine Persistent Disk (GCP PD)
- Azure File
- VMware vSphere

CSI migration for these volume types is considered generally available (GA), and requires no manual intervention.

CSI automatic migration of in-tree persistent volumes (PVs) or persistent volume claims (PVCs) does not enable any new CSI driver features, such as snapshots or expansion, if the original in-tree storage plugin did not support it.

5.7.2. Storage class implications

For new OpenShift Container Platform 4.13, and later, installations, the default storage class is the CSI storage class. All volumes provisioned using this storage class are CSI persistent volumes (PVs).

For clusters upgraded from 4.12, and earlier, to 4.13, and later, the CSI storage class is created, and is set as the default if no default storage class was set prior to the upgrade. In the very unlikely case that there is a storage class with the same name, the existing storage class remains unchanged. Any existing in-tree storage classes remain, and might be necessary for certain features, such as volume expansion to work for existing in-tree PVs. While storage class referencing to the in-tree storage plugin will continue working, we recommend that you switch the default storage class to the CSI storage class.

To change the default storage class, see Changing the default storage class .

5.8. AWS ELASTIC BLOCK STORE CSI DRIVER OPERATOR

5.8.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the AWS EBS CSI driver.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a Container Storage Interface (CSI) Operator and driver.

To create CSI-provisioned PVs that mount to AWS EBS storage assets, OpenShift Container Platform installs the AWS EBS CSI Driver Operator (a Red Hat operator) and the AWS EBS CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- The *AWS EBS CSI Driver Operator* provides a StorageClass by default that you can use to create PVCs. You can disable this default storage class if desired (see Managing the default storage class). You also have the option to create the AWS EBS StorageClass as described in Persistent storage using Amazon Elastic Block Store .
- The *AWS EBS CSI driver* enables you to create and mount AWS EBS PVs.

NOTE

If you installed the AWS EBS CSI Operator and driver on an OpenShift Container Platform 4.5 cluster, you must uninstall the 4.5 Operator and driver before you update to OpenShift Container Platform 4.18.

5.8.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

IMPORTANT

OpenShift Container Platform defaults to using the CSI plugin to provision Amazon Elastic Block Store (Amazon EBS) storage.

For information about dynamically provisioning AWS EBS persistent volumes in OpenShift Container Platform, see Persistent storage using Amazon Elastic Block Store .

5.8.3. User-managed encryption

The user-managed encryption feature allows you to provide keys during installation that encrypt OpenShift Container Platform node root volumes, and enables all managed storage classes to use these keys to encrypt provisioned storage volumes. You must specify the custom key in the **platform.<cloud_type>.defaultMachinePlatform** field in the install-config YAML file.

This features supports the following storage types:

- Amazon Web Services (AWS) Elastic Block storage (EBS)
- Microsoft Azure Disk storage
- Google Cloud Platform (GCP) persistent disk (PD) storage
- IBM Virtual Private Cloud (VPC) Block storage

NOTE

If there is no encrypted key defined in the storage class, only set **encrypted: "true"** in the storage class. The AWS EBS CSI driver uses the AWS managed alias/aws/ebs, which is created by Amazon EBS automatically in each region by default to encrypt provisioned storage volumes. In addition, the managed storage classes all have the **encrypted: "true"** setting.

For information about installing with user-managed encryption for Amazon EBS, see Installation configuration parameters.

Additional resources

- Persistent storage using Amazon Elastic Block Store

- Configuring CSI volumes

5.9. AWS ELASTIC FILE SERVICE CSI DRIVER OPERATOR

5.9.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for AWS Elastic File Service (EFS).

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

After installing the AWS EFS CSI Driver Operator, OpenShift Container Platform installs the AWS EFS CSI Operator and the AWS EFS CSI driver by default in the **openshift-cluster-csi-drivers** namespace. This allows the AWS EFS CSI Driver Operator to create CSI-provisioned PVs that mount to AWS EFS assets.

- The *AWS EFS CSI Driver Operator*, after being installed, does not create a storage class by default to use to create persistent volume claims (PVCs). However, you can manually create the AWS EFS **StorageClass**. The AWS EFS CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on-demand. This eliminates the need for cluster administrators to pre-provision storage.
- The *AWS EFS CSI driver* enables you to create and mount AWS EFS PVs.

NOTE

AWS EFS only supports regional volumes, not zonal volumes.

5.9.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.9.3. Setting up the AWS EFS CSI Driver Operator

1. If you are using AWS EFS with AWS Secure Token Service (STS), obtain a role Amazon Resource Name (ARN) for STS. This is required for installing the AWS EFS CSI Driver Operator.
2. Install the AWS EFS CSI Driver Operator.
3. Install the AWS EFS CSI Driver.

5.9.3.1. Obtaining a role Amazon Resource Name for Security Token Service

This procedure explains how to obtain a role Amazon Resource Name (ARN) to configure the AWS EFS CSI Driver Operator with OpenShift Container Platform on AWS Security Token Service (STS).

IMPORTANT

Perform this procedure before you install the AWS EFS CSI Driver Operator (see *Installing the AWS EFS CSI Driver Operator* procedure).

Prerequisites

- Access to the cluster as a user with the cluster-admin role.
- AWS account credentials

Procedure

You can obtain the ARN role in multiple ways. The following procedure shows one method that uses the same concept and CCO utility (**ccoctl**) binary tool as cluster installation.

To obtain a role ARN for configuring AWS EFS CSI Driver Operator using STS:

1. Extract the **ccoctl** from the OpenShift Container Platform release image, which you used to install the cluster with STS. For more information, see "Configuring the Cloud Credential Operator utility".
2. Create and save an EFS **CredentialsRequest** YAML file, such as shown in the following example, and then place it in the **credrequests** directory:

   Example

```
apiVersion: cloudcredential.openshift.io/v1
kind: CredentialsRequest
metadata:
  name: openshift-aws-efs-csi-driver
  namespace: openshift-cloud-credential-operator
spec:
  providerSpec:
    apiVersion: cloudcredential.openshift.io/v1
    kind: AWSProviderSpec
    statementEntries:
    - action:
      - elasticfilesystem:*
      effect: Allow
      resource: '*'
  secretRef:
    name: aws-efs-cloud-credentials
    namespace: openshift-cluster-csi-drivers
  serviceAccountNames:
  - aws-efs-csi-driver-operator
  - aws-efs-csi-driver-controller-sa
```

3. Run the **ccoctl** tool to generate a new IAM role in AWS, and create a YAML file for it in the local file system (**<path_to_ccoctl_output_dir>/manifests/openshift-cluster-csi-drivers-aws-efs-cloud-credentials-credentials.yaml**).

```
$ ccoctl aws create-iam-roles --name=<name> --region=<aws_region> --credentials-requests-dir=<path_to_directory_with_list_of_credentials_requests>/credrequests --identity-provider-arn=arn:aws:iam::<aws_account_id>:oidc-provider/<name>-oidc.s3.<aws_region>.amazonaws.com
```

- **name=<name>** is the name used to tag any cloud resources that are created for tracking.
- **region=<aws_region>** is the AWS region where cloud resources are created.
- **dir=<path_to_directory_with_list_of_credentials_requests>/credrequests** is the directory containing the EFS CredentialsRequest file in previous step.
- **<aws_account_id>** is the AWS account ID.

Example

```
$ ccoctl aws create-iam-roles --name my-aws-efs --credentials-requests-dir credrequests
--identity-provider-arn arn:aws:iam::123456789012:oidc-provider/my-aws-efs-oidc.s3.us-
east-2.amazonaws.com
```

Example output

```
2022/03/21 06:24:44 Role arn:aws:iam::123456789012:role/my-aws-efs -openshift-
cluster-csi-drivers-aws-efs-cloud- created
2022/03/21 06:24:44 Saved credentials configuration to: /manifests/openshift-cluster-csi-
drivers-aws-efs-cloud-credentials-credentials.yaml
2022/03/21 06:24:45 Updated Role policy for Role my-aws-efs-openshift-cluster-csi-
drivers-aws-efs-cloud-
```

4. Copy the role ARN from the first line of the *Example output* in the preceding step. The role ARN is between "Role" and "created". In this example, the role ARN is "arn:aws:iam::123456789012:role/my-aws-efs -openshift-cluster-csi-drivers-aws-efs-cloud". You will need the role ARN when you install the AWS EFS CSI Driver Operator.

Next steps

Install the AWS EFS CSI Driver Operator .

Additional resources

- Installing the AWS EFS CSI Driver Operator
- Configuring the Cloud Credential Operator utility
- Installing the AWS EFS CSI Driver

5.9.3.2. Installing the AWS EFS CSI Driver Operator

The AWS EFS CSI Driver Operator (a Red Hat Operator) is not installed in OpenShift Container Platform by default. Use the following procedure to install and configure the AWS EFS CSI Driver Operator in your cluster.

Prerequisites

- Access to the OpenShift Container Platform web console.

Procedure

To install the AWS EFS CSI Driver Operator from the web console:

1. Log in to the web console.
2. Install the AWS EFS CSI Operator:
   a. Click **Operators → OperatorHub**.
   b. Locate the AWS EFS CSI Operator by typing **AWS EFS CSI** in the filter box.
   c. Click the **AWS EFS CSI Driver Operator** button.

IMPORTANT

Be sure to select the **AWS EFS CSI Driver Operator** and not the **AWS EFS Operator**. The **AWS EFS Operator** is a community Operator and is not supported by Red Hat.

   a. On the **AWS EFS CSI Driver Operator** page, click **Install**.
   b. On the **Install Operator** page, ensure that:
      - If you are using AWS EFS with AWS Secure Token Service (STS), in the **role ARN** field, enter the ARN role copied from the last step of the *Obtaining a role Amazon Resource Name for Security Token Service* procedure.
      - **All namespaces on the cluster (default)** is selected.
      - **Installed Namespace** is set to **openshift-cluster-csi-drivers**.
   c. Click **Install**.
   After the installation finishes, the AWS EFS CSI Operator is listed in the **Installed Operators** section of the web console.

Next steps

Install the AWS EFS CSI Driver .

5.9.3.3. Installing the AWS EFS CSI Driver

After installing the AWS EFS CSI Driver Operator (a Red Hat operator), you install the AWS EFS CSI driver.

Prerequisites

- Access to the OpenShift Container Platform web console.

Procedure

1. Click **Administration → CustomResourceDefinitions → ClusterCSIDriver**.
2. On the **Instances** tab, click **Create ClusterCSIDriver**.
3. Use the following YAML file:

```
apiVersion: operator.openshift.io/v1
kind: ClusterCSIDriver
metadata:
```

```
    name: efs.csi.aws.com
spec:
  managementState: Managed
```

4. Click **Create**.
5. Wait for the following Conditions to change to a "True" status:
   - AWSEFSDriverNodeServiceControllerAvailable
   - AWSEFSDriverControllerServiceControllerAvailable

5.9.4. Creating the AWS EFS storage class

Storage classes are used to differentiate and delineate storage levels and usages. By defining a storage class, users can obtain dynamically provisioned persistent volumes.

The *AWS EFS CSI Driver Operator (a Red Hat operator)*, after being installed, does not create a storage class by default. However, you can manually create the AWS EFS storage class.

5.9.4.1. Creating the AWS EFS storage class using the console

Procedure

1. In the OpenShift Container Platform console, click **Storage → StorageClasses**.
2. On the **StorageClasses** page, click **Create StorageClass**.
3. On the **StorageClass** page, perform the following steps:
   a. Enter a name to reference the storage class.
   b. Optional: Enter the description.
   c. Select the reclaim policy.
   d. Select **efs.csi.aws.com** from the **Provisioner** drop-down list.
   e. Optional: Set the configuration parameters for the selected provisioner.
4. Click **Create**.

5.9.4.2. Creating the AWS EFS storage class using the CLI

Procedure

- Create a **StorageClass** object:

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: efs-sc
provisioner: efs.csi.aws.com
parameters:
  provisioningMode: efs-ap 1
```

```
fileSystemId: fs-a5324911 2
directoryPerms: "700" 3
gidRangeStart: "1000" 4
gidRangeEnd: "2000" 5
basePath: "/dynamic_provisioning" 6
```

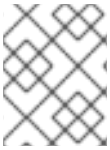
1. **provisioningMode** must be **efs-ap** to enable dynamic provisioning.
2. **fileSystemId** must be the ID of the EFS volume created manually.
3. **directoryPerms** is the default permission of the root directory of the volume. In this example, the volume is accessible only by the owner.
4. 5. **gidRangeStart** and **gidRangeEnd** set the range of POSIX Group IDs (GIDs) that are used to set the GID of the AWS access point. If not specified, the default range is 50000-7000000. Each provisioned volume, and thus AWS access point, is assigned a unique GID from this range.
6. **basePath** is the directory on the EFS volume that is used to create dynamically provisioned volumes. In this case, a PV is provisioned as "/dynamic_provisioning/<random uuid>" on the EFS volume. Only the subdirectory is mounted to pods that use the PV.

NOTE

A cluster admin can create several **StorageClass** objects, each using a different EFS volume.

5.9.5. AWS EFS CSI cross account support

Cross account support allows you to have an OpenShift Container Platform cluster in one AWS account and mount your file system in another AWS account by using the AWS Elastic File System (EFS) Container Storage Interface (CSI) driver.



NOTE

Both the OpenShift Container Platform cluster and EFS file system must be in the same region.

Prerequisites

- Access to an OpenShift Container Platform cluster with administrator rights
- Two valid AWS accounts

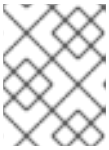
Procedure

The following procedure demonstrates how to set up:

- OpenShift Container Platform cluster in AWS account A
- Mount an AWS EFS file system in account B

To use AWS EFS across accounts:

1. Install OpenShift Container Platform cluster with AWS account A and install the EFS CSI Driver Operator.
2. Create an EFS volume in AWS account B:
   a. Create a virtual private cloud (VPC) called, for example, "my-efs-vpc" with CIDR, for example, "172.20.0.0/16" and subnet for the AWS EFS volume.
   b. On the AWS console, go to https://console.aws.amazon.com/efs.
   c. Click **Create new filesystem**:
      i. Create a filesystem named, for example, "my-filesystem".
      ii. Select the VPC created earlier ("my-efs-vpc").
      iii. Accept the default for the remaining settings.
   d. Ensure that the volume and Mount Targets have been created:
      i. Check https://console.aws.amazon.com/efs#/file-systems.
      ii. Click your volume, and on the **Network** tab wait for all Mount Targets to be available (approximately 1-2 minutes).
   e. On the **Network** tab, copy the Security Group ID. You will need it for the next step.
3. Configure networking access to the AWS EFS volume on AWS account B:
   a. Go to https://console.aws.amazon.com/ec2/v2/home#SecurityGroups.
   b. Find the Security Group used by the AWS EFS volume by filtering for the group ID copied earlier.
   c. On the **Inbound rules** tab, click **Edit inbound rules**, and then add a new rule to allow OpenShift Container Platform nodes to access the AWS EFS volumes (that is, use NFS ports from the cluster):
      - **Type**: NFS
      - **Protocol**: TCP
      - **Port range**: 2049
      - **Source**: Custom/IP address range of your OpenShift Container Platform cluster nodes (for example, "10.0.0.0/16")
   d. Save the rule.



NOTE

If you encounter mounting issues, re-check the port number, IP address range, and verify that the AWS EFS volume uses the expected security group.

4. Create VPC peering between the OpenShift Container Platform cluster VPC in AWS account A and the AWS EFS VPC in AWS account B:

Ensure the two VPCs are using different network CIDRs, and after creating the VPC peering, add routes in each VPC to connect the two VPC networks.

a. Create a peering connection called, for example, “my-efs-crossaccount-peering-connection” in account B. For the local VPC ID, use the EFS-located VPC. To peer with the VPC for account A, for the VPC ID use the OpenShift Container Platform cluster VPC ID.

b. Accept the peer connection in AWS account A.

c. Modify the route table of each subnet (EFS-volume used subnets) in AWS account B:

   i. On the left pane, under **Virtual private cloud**, click the down arrow to expand the available options.

   ii. Under **Virtual private cloud**, click **Route tables**".

   iii. Click the **Routes** tab.

   iv. Under **Destination**, enter 10.0.0.0/16.

   v. Under **Target**, use the peer connection type point from the created peer connection.

d. Modify the route table of each subnet (OpenShift Container Platform cluster nodes used subnets) in AWS account A:

   i. On the left pane, under **Virtual private cloud**, click the down arrow to expand the available options.

   ii. Under **Virtual private cloud**, click **Route tables**".

   iii. Click the **Routes** tab.

   iv. Under **Destination**, enter the CIDR for the VPC in account B, which for this example is 172.20.0.0/16.

   v. Under **Target**, use the peer connection type point from the created peer connection.

1. Create an IAM role, for example, “my-efs-acrossaccount-role” in AWS account B, which has a trust relationship with AWS account A, and add an inline AWS EFS policy with permissions to call “my-efs-acrossaccount-driver-policy”.
   This role is used by the CSI driver’s controller service running on the OpenShift Container Platform cluster in AWS account A to determine the mount targets for your file system in AWS account B.

```
# Trust relationships trusted entity trusted account A configuration on my-efs-acrossaccount-role in account B

{
   "Version": "2012-10-17",
   "Statement": [
      {
         "Sid": "VisualEditor0",
         "Effect": "Allow",
         "Action": [
            "ec2:DescribeNetworkInterfaces",
            "ec2:DescribeSubnets"
         ],
```

```
            "Resource": "*"
        },
        {
            "Sid": "VisualEditor1",
            "Effect": "Allow",
            "Action": [
                "elasticfilesystem:DescribeMountTargets",
                "elasticfilesystem:DeleteAccessPoint",
                "elasticfilesystem:ClientMount",
                "elasticfilesystem:DescribeAccessPoints",
                "elasticfilesystem:ClientWrite",
                "elasticfilesystem:ClientRootAccess",
                "elasticfilesystem:DescribeFileSystems",
                "elasticfilesystem:CreateAccessPoint"
            ],
            "Resource": [
                "arn:aws:elasticfilesystem:*:589722580343:access-point/*",
                "arn:aws:elasticfilesystem:*:589722580343:file-system/*"
            ]
        }
    ]
}
```

2. In AWS account A, attach an inline policy to the IAM role of the AWS EFS CSI driver's controller service account with the necessary permissions to perform Security Token Service (STS) assume role on the IAM role created earlier.

```
# my-cross-account-assume-policy policy attached to Openshift cluster efs csi driver user in account A

{
    "Version": "2012-10-17",
    "Statement": {
        "Effect": "Allow",
        "Action": "sts:AssumeRole",
        "Resource": "arn:aws:iam::589722580343:role/my-efs-acrossaccount-role"
    }
}
```

3. In AWS account A, attach the AWS-managed policy "AmazonElasticFileSystemClientFullAccess" to OpenShift Container Platform cluster master role. The role name is in the form **<clusterID>-master-role** (for example, **my-0120ef-czjrl-master-role**).

4. Create a Kubernetes secret with **awsRoleArn** as the key and the role created earlier as the value:

```
$ oc -n openshift-cluster-csi-drivers create secret generic my-efs-cross-account --from-literal=awsRoleArn='arn:aws:iam::589722580343:role/my-efs-acrossaccount-role'
```

Since the driver controller needs to get the cross account role information from the secret, you need to add the secret role binding to the AWS EFS CSI driver controller ServiceAccount (SA):

```
$ oc -n openshift-cluster-csi-drivers create role access-secrets --verb=get,list,watch --resource=secrets
```

```
$ oc -n openshift-cluster-csi-drivers create rolebinding --role=access-secrets default-to-secrets --serviceaccount=openshift-cluster-csi-drivers:aws-efs-csi-driver-controller-sa
```

5. Create a **filesystem** policy for the file system (AWS EFS volume) in account B, which allows AWS account A to perform a mount on it.

NOTE

This step is not mandatory, but can be safer for AWS EFS volume usage.

```
# EFS volume filesystem policy in account B
{
    "Version": "2012-10-17",
    "Id": "efs-policy-wizard-8089bf4a-9787-40f0-958e-bc2363012ace",
    "Statement": [
        {
            "Sid": "efs-statement-bd285549-cfa2-4f8b-861e-c372399fd238",
            "Effect": "Allow",
            "Principal": {
                "AWS": "*"
            },
            "Action": [
                "elasticfilesystem:ClientRootAccess",
                "elasticfilesystem:ClientWrite",
                "elasticfilesystem:ClientMount"
            ],
            "Resource": "arn:aws:elasticfilesystem:us-east-2:589722580343:file-system/fs-091066a9bf9becbd5",
            "Condition": {
                "Bool": {
                    "elasticfilesystem:AccessedViaMountTarget": "true"
                }
            }
        },
        {
            "Sid": "efs-statement-03646e39-d80f-4daf-b396-281be1e43bab",
            "Effect": "Allow",
            "Principal": {
                "AWS": "arn:aws:iam::589722580343:role/my-efs-acrossaccount-role"
            },
            "Action": [
                "elasticfilesystem:ClientRootAccess",
                "elasticfilesystem:ClientWrite",
                "elasticfilesystem:ClientMount"
            ],
            "Resource": "arn:aws:elasticfilesystem:us-east-2:589722580343:file-system/fs-091066a9bf9becbd5"
        }
    ]
}
```

6. Create an AWS EFS volume storage class using a similar configuration to the following:

```
# The cross account efs volume storageClass
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
name: efs-cross-account-mount-sc
provisioner: efs.csi.aws.com
mountOptions:
- tls
parameters:
provisioningMode: efs-ap
fileSystemId: fs-00f6c3ae6f06388bb
directoryPerms: "700"
gidRangeStart: "1000"
gidRangeEnd: "2000"
basePath: "/account-a-data"
csi.storage.k8s.io/provisioner-secret-name: my-efs-cross-account
csi.storage.k8s.io/provisioner-secret-namespace: openshift-cluster-csi-drivers
volumeBindingMode: Immediate
```

5.9.6. Creating and configuring access to EFS volumes in AWS

This procedure explains how to create and configure EFS volumes in AWS so that you can use them in OpenShift Container Platform.

Prerequisites

- AWS account credentials

Procedure

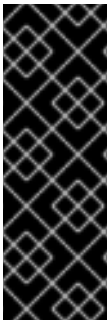
To create and configure access to an EFS volume in AWS:

1. On the AWS console, open https://console.aws.amazon.com/efs.
2. Click **Create file system**
   - Enter a name for the file system.
   - For **Virtual Private Cloud (VPC)** select your OpenShift Container Platform's' virtual private cloud (VPC).
   - Accept default settings for all other selections.
3. Wait for the volume and mount targets to finish being fully created:
   a. Go to https://console.aws.amazon.com/efs#/file-systems.
   b. Click your volume, and on the **Network** tab wait for all mount targets to become available (~1-2 minutes).
4. On the **Network** tab, copy the Security Group ID (you will need this in the next step).
5. Go to https://console.aws.amazon.com/ec2/v2/home#SecurityGroups, and find the Security Group used by the EFS volume.

6. On the **Inbound rules** tab, click **Edit inbound rules**, and then add a new rule with the following settings to allow OpenShift Container Platform nodes to access EFS volumes :
   - **Type**: NFS
   - **Protocol**: TCP
   - **Port range**: 2049
   - **Source**: Custom/IP address range of your nodes (for example: "10.0.0.0/16")
     This step allows OpenShift Container Platform to use NFS ports from the cluster.
7. Save the rule.

5.9.7. Dynamic provisioning for Amazon Elastic File Storage

The AWS EFS CSI driver supports a different form of dynamic provisioning than other CSI drivers. It provisions new PVs as subdirectories of a pre-existing EFS volume. The PVs are independent of each other. However, they all share the same EFS volume. When the volume is deleted, all PVs provisioned out of it are deleted too. The EFS CSI driver creates an AWS Access Point for each such subdirectory. Due to AWS AccessPoint limits, you can only dynamically provision 1000 PVs from a single **StorageClass**/EFS volume.



IMPORTANT

Note that **PVC.spec.resources** is not enforced by EFS.

In the example below, you request 5 GiB of space. However, the created PV is limitless and can store any amount of data (like petabytes). A broken application, or even a rogue application, can cause significant expenses when it stores too much data on the volume.

Using monitoring of EFS volume sizes in AWS is strongly recommended.

Prerequisites

- You have created Amazon Elastic File Storage (Amazon EFS) volumes.
- You have created the AWS EFS storage class.

Procedure

To enable dynamic provisioning:

- Create a PVC (or StatefulSet or Template) as usual, referring to the **StorageClass** created previously.

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: test
spec:
  storageClassName: efs-sc
  accessModes:
    - ReadWriteMany
```

```
  resources:
    requests:
      storage: 5Gi
```

If you have problems setting up dynamic provisioning, see AWS EFS troubleshooting.

Additional resources

- Creating and configuring access to AWS EFS volume(s)
- Creating the AWS EFS storage class

5.9.8. Creating static PVs with Amazon Elastic File Storage

It is possible to use an Amazon Elastic File Storage (Amazon EFS) volume as a single PV without any dynamic provisioning. The whole volume is mounted to pods.

Prerequisites

- You have created Amazon EFS volumes.

Procedure

- Create the PV using the following YAML file:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: efs-pv
spec:
  capacity: 1
    storage: 5Gi
  volumeMode: Filesystem
  accessModes:
    - ReadWriteMany
    - ReadWriteOnce
  persistentVolumeReclaimPolicy: Retain
  csi:
    driver: efs.csi.aws.com
    volumeHandle: fs-ae66151a 2
    volumeAttributes:
      encryptInTransit: "false" 3
```

1. **spec.capacity** does not have any meaning and is ignored by the CSI driver. It is used only when binding to a PVC. Applications can store any amount of data to the volume.
2. **volumeHandle** must be the same ID as the EFS volume you created in AWS. If you are providing your own access point, **volumeHandle** should be **<EFS volume ID>::<access point ID>**. For example: **fs-6e633ada::fsap-081a1d293f0004630**.
3. If desired, you can disable encryption in transit. Encryption is enabled by default.

If you have problems setting up static PVs, see AWS EFS troubleshooting.

5.9.9. Amazon Elastic File Storage security

The following information is important for Amazon Elastic File Storage (Amazon EFS) security.

When using access points, for example, by using dynamic provisioning as described earlier, Amazon automatically replaces GIDs on files with the GID of the access point. In addition, EFS considers the user ID, group ID, and secondary group IDs of the access point when evaluating file system permissions. EFS ignores the NFS client's IDs. For more information about access points, see https://docs.aws.amazon.com/efs/latest/ug/efs-access-points.html.

As a consequence, EFS volumes silently ignore FSGroup; OpenShift Container Platform is not able to replace the GIDs of files on the volume with FSGroup. Any pod that can access a mounted EFS access point can access any file on it.

Unrelated to this, encryption in transit is enabled by default. For more information, see https://docs.aws.amazon.com/efs/latest/ug/encryption-in-transit.html.

5.9.10. AWS EFS storage CSI usage metrics

5.9.10.1. Usage metrics overview

Amazon Web Services (AWS) Elastic File Service (EFS) storage Container Storage Interface (CSI) usage metrics allow you to monitor how much space is used by either dynamically or statically provisioned EFS volumes.

IMPORTANT

This features is disabled by default, because turning on metrics can lead to performance degradation.

The AWS EFS usage metrics feature collects volume metrics in the AWS EFS CSI Driver by recursively walking through the files in the volume. Because this effort can degrade performance, administrators must explicitly enable this feature.

5.9.10.2. Enabling usage metrics using the web console

To enable Amazon Web Services (AWS) Elastic File Service (EFS) Storage Container Storage Interface (CSI) usage metrics using the web console:

1. Click **Administration** > **CustomResourceDefinitions**.
2. On the **CustomResourceDefinitions** page next to the **Name** dropdown box, type **clustercsidriver**.
3. Click **CRD ClusterCSIDriver**.
4. Click the **YAML** tab.
5. Under **spec.aws.efsVolumeMetrics.state**, set the value to **RecursiveWalk**. **RecursiveWalk** indicates that volume metrics collection in the AWS EFS CSI Driver is performed by recursively walking through the files in the volume.

   Example ClusterCSIDriver efs.csi.aws.com YAML file

```
spec:
  driverConfig:
    driverType: AWS
    aws:
      efsVolumeMetrics:
        state: RecursiveWalk
        recursiveWalk:
          refreshPeriodMinutes: 100
          fsRateLimit: 10
```

6. Optional: To define how the recursive walk operates, you can also set the following fields:
   - **refreshPeriodMinutes**: Specifies the refresh frequency for volume metrics in minutes. If this field is left blank, a reasonable default is chosen, which is subject to change over time. The current default is 240 minutes. The valid range is 1 to 43,200 minutes.
   - **fsRateLimit**: Defines the rate limit for processing volume metrics in goroutines per file system. If this field is left blank, a reasonable default is chosen, which is subject to change over time. The current default is 5 goroutines. The valid range is 1 to 100 goroutines.
7. Click **Save**.

NOTE

To **disable** AWS EFS CSI usage metrics, use the preceding procedure, but for **spec.aws.efsVolumeMetrics.state**, change the value from **RecursiveWalk** to **Disabled**.

5.9.10.3. Enabling usage metrics using the CLI

To enable Amazon Web Services (AWS) Elastic File Service (EFS) storage Container Storage Interface (CSI) usage metrics using the CLI:

1. Edit ClusterCSIDriver by running the following command:

```
$ oc edit clustercsidriver efs.csi.aws.com
```

2. Under **spec.aws.efsVolumeMetrics.state**, set the value to **RecursiveWalk**. **RecursiveWalk** indicates that volume metrics collection in the AWS EFS CSI Driver is performed by recursively walking through the files in the volume.

   Example ClusterCSIDriver efs.csi.aws.com YAML file

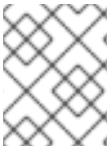
```
spec:
  driverConfig:
    driverType: AWS
    aws:
      efsVolumeMetrics:
        state: RecursiveWalk
        recursiveWalk:
          refreshPeriodMinutes: 100
          fsRateLimit: 10
```

3. Optional: To define how the recursive walk operates, you can also set the following fields:
   - **refreshPeriodMinutes**: Specifies the refresh frequency for volume metrics in minutes. If

this field is left blank, a reasonable default is chosen, which is subject to change over time. The current default is 240 minutes. The valid range is 1 to 43,200 minutes.

- **fsRateLimit**: Defines the rate limit for processing volume metrics in goroutines per file system. If this field is left blank, a reasonable default is chosen, which is subject to change over time. The current default is 5 goroutines. The valid range is 1 to 100 goroutines.

4. Save the changes to the **efs.csi.aws.com** object.



NOTE

To **disable** AWS EFS CSI usage metrics, use the preceding procedure, but for **spec.aws.efsVolumeMetrics.state**, change the value from **RecursiveWalk** to **Disabled**.

5.9.11. Amazon Elastic File Storage troubleshooting

The following information provides guidance on how to troubleshoot issues with Amazon Elastic File Storage (Amazon EFS):

- The AWS EFS Operator and CSI driver run in namespace **openshift-cluster-csi-drivers**.
- To initiate gathering of logs of the AWS EFS Operator and CSI driver, run the following command:

```
$ oc adm must-gather
[must-gather      ] OUT Using must-gather plugin-in image: quay.io/openshift-release-dev/ocp-v4.0-art-dev@sha256:125f183d13601537ff15b3239df95d47f0a604da2847b561151fedd699f5e3a5
[must-gather      ] OUT namespace/openshift-must-gather-xm4wq created
[must-gather      ] OUT clusterrolebinding.rbac.authorization.k8s.io/must-gather-2bd8x created
[must-gather      ] OUT pod for plug-in image quay.io/openshift-release-dev/ocp-v4.0-art-dev@sha256:125f183d13601537ff15b3239df95d47f0a604da2847b561151fedd699f5e3a5 created
```

- To show AWS EFS Operator errors, view the **ClusterCSIDriver** status:

```
$ oc get clustercsidriver efs.csi.aws.com -o yaml
```

- If a volume cannot be mounted to a pod (as shown in the output of the following command):

```
$ oc describe pod
...
  Type     Reason       Age    From               Message
  ----     ------       ----   ----               -------
  Normal   Scheduled    2m13s  default-scheduler  Successfully assigned default/efs-app to ip-10-0-135-94.ec2.internal
  Warning  FailedMount  13s    kubelet            MountVolume.SetUp failed for volume "pvc-d7c097e6-67ec-4fae-b968-7e7056796449" : rpc error: code = DeadlineExceeded desc = context deadline exceeded (1)
  Warning  FailedMount  10s    kubelet            Unable to attach or mount volumes: unmounted volumes=[persistent-storage], unattached volumes=[persistent-storage kube-api-access-9j477]: timed out waiting for the condition
```

1 Warning message indicating volume not mounted.

This error is frequently caused by AWS dropping packets between an OpenShift Container Platform node and Amazon EFS.

Check that the following are correct:

- AWS firewall and Security Groups
- Networking: port number and IP addresses

5.9.12. Uninstalling the AWS EFS CSI Driver Operator

All EFS PVs are inaccessible after uninstalling the AWS EFS CSI Driver Operator (a Red Hat operator).

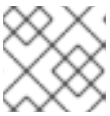
Prerequisites

- Access to the OpenShift Container Platform web console.

Procedure

To uninstall the AWS EFS CSI Driver Operator from the web console:

1. Log in to the web console.
2. Stop all applications that use AWS EFS PVs.
3. Delete all AWS EFS PVs:
   a. Click **Storage → PersistentVolumeClaims**.
   b. Select each PVC that is in use by the AWS EFS CSI Driver Operator, click the drop-down menu on the far right of the PVC, and then click **Delete PersistentVolumeClaims**.
4. Uninstall the AWS EFS CSI driver:



NOTE

Before you can uninstall the Operator, you must remove the CSI driver first.

   a. Click **Administration → CustomResourceDefinitions → ClusterCSIDriver**.
   b. On the **Instances** tab, for **efs.csi.aws.com**, on the far left side, click the drop-down menu, and then click **Delete ClusterCSIDriver**.
   c. When prompted, click **Delete**.
5. Uninstall the AWS EFS CSI Operator:
   a. Click **Operators → Installed Operators**.
   b. On the **Installed Operators** page, scroll or type AWS EFS CSI into the **Search by name** box to find the Operator, and then click it.
   c. On the upper, right of the **Installed Operators > Operator details**page, click **Actions → Uninstall Operator**.

d. When prompted on the **Uninstall Operator** window, click the **Uninstall** button to remove the Operator from the namespace. Any applications deployed by the Operator on the cluster need to be cleaned up manually.
After uninstalling, the AWS EFS CSI Driver Operator is no longer listed in the **Installed Operators** section of the web console.

NOTE

Before you can destroy a cluster (**openshift-install destroy cluster**), you must delete the EFS volume in AWS. An OpenShift Container Platform cluster cannot be destroyed when there is an EFS volume that uses the cluster's VPC. Amazon does not allow deletion of such a VPC.

5.9.13. Additional resources

- Configuring CSI volumes

5.10. AZURE DISK CSI DRIVER OPERATOR

5.10.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for Microsoft Azure Disk Storage.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

To create CSI-provisioned PVs that mount to Azure Disk storage assets, OpenShift Container Platform installs the Azure Disk CSI Driver Operator and the Azure Disk CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- The *Azure Disk CSI Driver Operator* provides a storage class named **managed-csi** that you can use to create persistent volume claims (PVCs). The Azure Disk CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on-demand, eliminating the need for cluster administrators to pre-provision storage. You can disable this default storage class if desired (see Managing the default storage class).
- The *Azure Disk CSI driver* enables you to create and mount Azure Disk PVs.

5.10.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

NOTE

OpenShift Container Platform provides automatic migration for the Azure Disk in-tree volume plugin to its equivalent CSI driver. For more information, see CSI automatic migration.

5.10.3. Creating a storage class with storage account type

Storage classes are used to differentiate and delineate storage levels and usages. By defining a storage class, you can obtain dynamically provisioned persistent volumes.

When creating a storage class, you can designate the storage account type. This corresponds to your Azure storage account SKU tier. Valid options are **Standard_LRS**, **Premium_LRS**, **StandardSSD_LRS**, **UltraSSD_LRS**, **Premium_ZRS**, **StandardSSD_ZRS**, and **PremiumV2_LRS**. For information about finding your Azure SKU tier, see SKU Types.

Both ZRS and PremiumV2_LRS have some region limitations. For information about these limitations, see ZRS limitations and Premium_LRS limitations.

Prerequisites

- Access to an OpenShift Container Platform cluster with administrator rights

Procedure

Use the following steps to create a storage class with a storage account type.

1. Create a storage class designating the storage account type using a YAML file similar to the following:

```
$ oc create -f - << EOF
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <storage-class> 1
provisioner: disk.csi.azure.com
parameters:
  skuName: <storage-class-account-type> 2
reclaimPolicy: Delete
volumeBindingMode: WaitForFirstConsumer
allowVolumeExpansion: true
EOF
```

1. Storage class name.
2. Storage account type. This corresponds to your Azure storage account SKU tier:`Standard_LRS`, **Premium_LRS**, **StandardSSD_LRS**, **UltraSSD_LRS**, **Premium_ZRS**, **StandardSSD_ZRS**, **PremiumV2_LRS**.

NOTE

For PremiumV2_LRS, specify **cachingMode: None** in **storageclass.parameters**.

2. Ensure that the storage class was created by listing the storage classes:

```
$ oc get storageclass
```

Example output

```
$ oc get storageclass
```

```
NAME                 PROVISIONER          RECLAIMPOLICY   VOLUMEBINDINGMODE
ALLOWVOLUMEEXPANSION   AGE
azurefile-csi        file.csi.azure.com   Delete          Immediate
true                   68m
managed-csi (default)   disk.csi.azure.com   Delete          WaitForFirstConsumer   true
68m
sc-prem-zrs          disk.csi.azure.com   Delete          WaitForFirstConsumer   true
4m25s 1
```

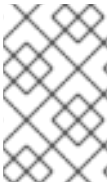
1 New storage class with storage account type.

5.10.4. User-managed encryption

The user-managed encryption feature allows you to provide keys during installation that encrypt OpenShift Container Platform node root volumes, and enables all managed storage classes to use these keys to encrypt provisioned storage volumes. You must specify the custom key in the **platform.<cloud_type>.defaultMachinePlatform** field in the install-config YAML file.

This features supports the following storage types:

- Amazon Web Services (AWS) Elastic Block storage (EBS)
- Microsoft Azure Disk storage
- Google Cloud Platform (GCP) persistent disk (PD) storage
- IBM Virtual Private Cloud (VPC) Block storage



NOTE

If the OS (root) disk is encrypted, and there is no encrypted key defined in the storage class, Azure Disk CSI driver uses the OS disk encryption key by default to encrypt provisioned storage volumes.

For information about installing with user-managed encryption for Azure, see Enabling user-managed encryption for Azure.

5.10.5. Machine sets that deploy machines with ultra disks using PVCs

You can create a machine set running on Azure that deploys machines with ultra disks. Ultra disks are high-performance storage that are intended for use with the most demanding data workloads.

Both the in-tree plugin and CSI driver support using PVCs to enable ultra disks. You can also deploy machines with ultra disks as data disks without creating a PVC.

Additional resources

- Microsoft Azure ultra disks documentation
- Machine sets that deploy machines on ultra disks using in-tree PVCs
- Machine sets that deploy machines on ultra disks as data disks

5.10.5.1. Creating machines with ultra disks by using machine sets

You can deploy machines with ultra disks on Azure by editing your machine set YAML file.

Prerequisites

- Have an existing Microsoft Azure cluster.

Procedure

1. Copy an existing Azure **MachineSet** custom resource (CR) and edit it by running the following command:

```
$ oc edit machineset <machine_set_name>
```

   where **<machine_set_name>** is the machine set that you want to provision machines with ultra disks.

2. Add the following lines in the positions indicated:

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
spec:
  template:
    spec:
      metadata:
        labels:
          disk: ultrassd 1
      providerSpec:
        value:
          ultraSSDCapability: Enabled 2
```

   1 Specify a label to use to select a node that is created by this machine set. This procedure uses **disk.ultrassd** for this value.

   2 These lines enable the use of ultra disks.

3. Create a machine set using the updated configuration by running the following command:

```
$ oc create -f <machine_set_name>.yaml
```

4. Create a storage class that contains the following YAML definition:

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: ultra-disk-sc 1
parameters:
  cachingMode: None
  diskIopsReadWrite: "2000" 2
  diskMbpsReadWrite: "320" 3
  kind: managed
  skuname: UltraSSD_LRS
```

```
provisioner: disk.csi.azure.com 4
reclaimPolicy: Delete
volumeBindingMode: WaitForFirstConsumer 5
```

1. Specify the name of the storage class. This procedure uses **ultra-disk-sc** for this value.
2. Specify the number of IOPS for the storage class.
3. Specify the throughput in MBps for the storage class.
4. For Azure Kubernetes Service (AKS) version 1.21 or later, use **disk.csi.azure.com**. For earlier versions of AKS, use **kubernetes.io/azure-disk**.
5. Optional: Specify this parameter to wait for the creation of the pod that will use the disk.

5. Create a persistent volume claim (PVC) to reference the **ultra-disk-sc** storage class that contains the following YAML definition:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: ultra-disk 1
spec:
  accessModes:
  - ReadWriteOnce
  storageClassName: ultra-disk-sc 2
  resources:
    requests:
      storage: 4Gi 3
```

1. Specify the name of the PVC. This procedure uses **ultra-disk** for this value.
2. This PVC references the **ultra-disk-sc** storage class.
3. Specify the size for the storage class. The minimum value is **4Gi**.

6. Create a pod that contains the following YAML definition:

```
apiVersion: v1
kind: Pod
metadata:
  name: nginx-ultra
spec:
  nodeSelector:
    disk: ultrassd 1
  containers:
  - name: nginx-ultra
    image: alpine:latest
    command:
      - "sleep"
      - "infinity"
    volumeMounts:
    - mountPath: "/mnt/azure"
```

```
      name: volume
  volumes:
    - name: volume
      persistentVolumeClaim:
        claimName: ultra-disk 2
```

1 Specify the label of the machine set that enables the use of ultra disks. This procedure uses **disk.ultrassd** for this value.

2 This pod references the **ultra-disk** PVC.

Verification

1. Validate that the machines are created by running the following command:

```
$ oc get machines
```

   The machines should be in the **Running** state.

2. For a machine that is running and has a node attached, validate the partition by running the following command:

```
$ oc debug node/<node_name> -- chroot /host lsblk
```

   In this command, **oc debug node/<node_name>** starts a debugging shell on the node **<node_name>** and passes a command with **--**. The passed command **chroot /host** provides access to the underlying host OS binaries, and **lsblk** shows the block devices that are attached to the host OS machine.

Next steps

- To use an ultra disk from within a pod, create a workload that uses the mount point. Create a YAML file similar to the following example:

```
apiVersion: v1
kind: Pod
metadata:
  name: ssd-benchmark1
spec:
  containers:
  - name: ssd-benchmark1
    image: nginx
    ports:
      - containerPort: 80
        name: "http-server"
    volumeMounts:
    - name: lun0p1
      mountPath: "/tmp"
  volumes:
    - name: lun0p1
      hostPath:
        path: /var/lib/lun0p1
```

```
      type: DirectoryOrCreate
  nodeSelector:
    disktype: ultrassd
```

5.10.5.2. Troubleshooting resources for machine sets that enable ultra disks

Use the information in this section to understand and recover from issues you might encounter.

5.10.5.2.1. Unable to mount a persistent volume claim backed by an ultra disk

If there is an issue mounting a persistent volume claim backed by an ultra disk, the pod becomes stuck in the **ContainerCreating** state and an alert is triggered.

For example, if the **additionalCapabilities.ultraSSDEnabled** parameter is not set on the machine that backs the node that hosts the pod, the following error message appears:

```
StorageAccountType UltraSSD_LRS can be used only when additionalCapabilities.ultraSSDEnabled is set.
```

- To resolve this issue, describe the pod by running the following command:

  ```
  $ oc -n <stuck_pod_namespace> describe pod <stuck_pod_name>
  ```

5.10.6. Additional resources

- Persistent storage using Azure Disk
- Configuring CSI volumes

5.11. AZURE FILE CSI DRIVER OPERATOR

5.11.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) by using the Container Storage Interface (CSI) driver for Microsoft Azure File Storage.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

To create CSI-provisioned PVs that mount to Azure File storage assets, OpenShift Container Platform installs the Azure File CSI Driver Operator and the Azure File CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- The *Azure File CSI Driver Operator* provides a storage class that is named **azurefile-csi** that you can use to create persistent volume claims (PVCs). You can disable this default storage class if desired (see Managing the default storage class).
- The *Azure File CSI driver* enables you to create and mount Azure File PVs. The Azure File CSI driver supports dynamic volume provisioning by allowing storage volumes to be created on-demand, eliminating the need for cluster administrators to pre-provision storage.

Azure File CSI Driver Operator does not support:

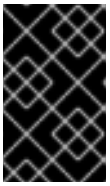
- Virtual hard disks (VHD)
- Running on nodes with Federal Information Processing Standard (FIPS) mode enabled for Server Message Block (SMB) file share. However, Network File System (NFS) does support FIPS mode.

For more information about supported features, see Supported CSI drivers and features .

5.11.2. NFS support

OpenShift Container Platform 4.14, and later, supports Azure File Container Storage Interface (CSI) Driver Operator with Network File System (NFS) with the following caveats:

- Creating pods with Azure File NFS volumes that are scheduled to the control plane node causes the mount to be denied.
  To work around this issue: If your control plane nodes are schedulable, and the pods can run on worker nodes, use **nodeSelector** or Affinity to schedule the pod in worker nodes.
- FS Group policy behavior:



IMPORTANT

Azure File CSI with NFS does not honor the fsGroupChangePolicy requested by pods. Azure File CSI with NFS applies a default OnRootMismatch FS Group policy regardless of the policy requested by the pod.

- The Azure File CSI Operator does not automatically create a storage class for NFS. You must create it manually. Use a file similar to the following:

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <storage-class-name> 1
provisioner: file.csi.azure.com 2
parameters:
  protocol: nfs 3
  skuName: Premium_LRS  # available values: Premium_LRS, Premium_ZRS
mountOptions:
  - nconnect=4
```

1. Storage class name.
2. Specifies the Azure File CSI provider.
3. Specifies NFS as the storage backend protocol.

5.11.3. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

Additional resources

- Persistent storage using Azure File
- Configuring CSI volumes

5.12. AZURE STACK HUB CSI DRIVER OPERATOR

5.12.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for Azure Stack Hub Storage. Azure Stack Hub, which is part of the Azure Stack portfolio, allows you to run apps in an on-premise environment and deliver Azure services in your datacenter.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

To create CSI-provisioned PVs that mount to Azure Stack Hub storage assets, OpenShift Container Platform installs the Azure Stack Hub CSI Driver Operator and the Azure Stack Hub CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- The *Azure Stack Hub CSI Driver Operator* provides a storage class (**managed-csi**), with "Standard_LRS" as the default storage account type, that you can use to create persistent volume claims (PVCs). The Azure Stack Hub CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on-demand, eliminating the need for cluster administrators to pre-provision storage.
- The *Azure Stack Hub CSI driver* enables you to create and mount Azure Stack Hub PVs.

5.12.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.12.3. Additional resources

- Configuring CSI volumes

5.13. GCP PD CSI DRIVER OPERATOR

5.13.1. Overview

OpenShift Container Platform can provision persistent volumes (PVs) using the Container Storage Interface (CSI) driver for Google Cloud Platform (GCP) persistent disk (PD) storage.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a Container Storage Interface (CSI) Operator and driver.

To create CSI-provisioned persistent volumes (PVs) that mount to GCP PD storage assets, OpenShift Container Platform installs the GCP PD CSI Driver Operator and the GCP PD CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- **GCP PD CSI Driver Operator**: By default, the Operator provides a storage class that you can use to create PVCs. You can disable this default storage class if desired (see Managing the default storage class). You also have the option to create the GCP PD storage class as described in Persistent storage using GCE Persistent Disk .
- **GCP PD driver**: The driver enables you to create and mount GCP PD PVs.
  GCP PD CSI driver supports the C3 instance type for bare metal and N4 machine series. The C3 instance type and N4 machine series support the hyperdisk-balanced disks.

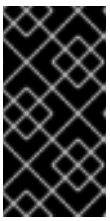
OpenShift Container Platform provides automatic migration for the GCE Persistent Disk in-tree volume plugin to its equivalent CSI driver. For more information, see CSI automatic migration .

5.13.2. C3 instance type for bare metal and N4 machine series

5.13.2.1. C3 and N4 instance type limitations

The GCP PD CSI driver support for the C3 instance type for bare metal and N4 machine series have the following limitations:

- Cloning volumes is not supported when using storage pools.
- For cloning or resizing, hyperdisk-balanced disks original volume size must be 6Gi or greater.
- The default storage class is standard-csi.



IMPORTANT

You need to manually create a storage class.

For information about creating the storage class, see Step 2 in Section *Setting up hyperdisk-balanced disks*.

- Clusters with mixed virtual machines (VMs) that use different storage types, for example, N2 and N4, are not supported. This is due to hyperdisks-balanced disks not being usable on most legacy VMs. Similarly, regular persistent disks are not usable on N4/C3 VMs.
- A GCP cluster with c3-standard-2, c3-standard-4, n4-standard-2, and n4-standard-4 nodes can erroneously exceed the maximum attachable disk number, which should be 16 (JIRA link).

5.13.2.2. Storage pools for hyperdisk-balanced disks overview

Hyperdisk storage pools can be used with Compute Engine for large-scale storage. A hyperdisk storage pool is a purchased collection of capacity, throughput, and IOPS, which you can then provision for your applications as needed. You can use hyperdisk storage pools to create and manage disks in pools and use the disks across multiple workloads. By managing disks in aggregate, you can save costs while achieving expected capacity and performance growth. By using only the storage that you need in hyperdisk storage pools, you reduce the complexity of forecasting capacity and reduce management by going from managing hundreds of disks to managing a single storage pool.

To set up storage pools, see Setting up hyperdisk-balanced disks.

5.13.2.3. Setting up hyperdisk-balanced disks

Prerequisites

- Access to the cluster with administrative privileges

Procedure

Complete the following steps to set up hyperdisk-balanced disks:

1. Create a GCP cluster with attached disks provisioned with hyperdisk-balanced disks.
2. Create a storage class specifying the hyperdisk-balanced disks during installation:
   a. Follow the procedure in the *Installing a cluster on GCP with customizations* section. For your install-config.yaml file, use the following example file:

Example install-config YAML file

```
apiVersion: v1
metadata:
  name: ci-op-9976b7t2-8aa6b

sshKey: |
  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
baseDomain: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
platform:
  gcp:
    projectID: XXXXXXXXXXXXXXXXXXXXX
    region: us-central1
controlPlane:
  architecture: amd64
  name: master
  platform:
    gcp:
      type: n4-standard-4 (1)
      osDisk:
        diskType: hyperdisk-balanced (2)
        diskSizeGB: 200
  replicas: 3
compute:
- architecture: amd64
  name: worker
  replicas: 3
  platform:
    gcp:
      type: n4-standard-4 (3)
      osDisk:
        diskType: hyperdisk-balanced (4)
```

(1) (3) Specifies the node type as n4-standard-4.

(2) (4)

Specifies the node has the root disk backed by hyperdisk-balanced disk type. All nodes in the cluster should use the same disk type, either hyperdisks-balanced or pd-*.

NOTE

All nodes in the cluster must support hyperdisk-balanced volumes. Clusters with mixed nodes are not supported, for example N2 and N3 using hyperdisk-balanced disks.

b. After step 3 in *Incorporating the Cloud Credential Operator utility manifests* section, copy the following manifests into the manifests directory created by the installation program:

- cluster_csi_driver.yaml - specifies opting out of the default storage class creation
- storageclass.yaml - creates a hyperdisk-specific storage class

Example cluster CSI driver YAML file

```
apiVersion: operator.openshift.io/v1
kind: "ClusterCSIDriver"
metadata:
  name: "pd.csi.storage.gke.io"
spec:
  logLevel: Normal
  managementState: Managed
  operatorLogLevel: Normal
  storageClassState: Unmanaged (1)
```

(1) Specifies disabling creation of the default OpenShift Container Platform storage classes.

Example storage class YAML file

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: hyperdisk-sc (1)
  annotations:
    storageclass.kubernetes.io/is-default-class: "true"
provisioner: pd.csi.storage.gke.io (2)
volumeBindingMode: WaitForFirstConsumer
allowVolumeExpansion: true
reclaimPolicy: Delete
parameters:
  type: hyperdisk-balanced (3)
  replication-type: none
  provisioned-throughput-on-create: "140Mi" (4)
  provisioned-iops-on-create: "3000" (5)
  storage-pools: projects/my-project/zones/us-east4-c/storagePools/pool-us-east4-c
(6)
allowedTopologies: (7)
- matchLabelExpressions:
```

```
    - key: topology.kubernetes.io/zone
      values:
      - us-east4-c
...
```

1. Specify the name for your storage class. In this example, it is **hyperdisk-sc**.
2. **pd.csi.storage.gke.io** specifies GCP CSI provisioner.
3. Specifies using hyperdisk-balanced disks.
4. Specifies the throughput value in MiBps using the "Mi" qualifier. For example, if your required throughput is 250 MiBps, specify "250Mi". If you do not specify a value, the capacity is based upon the disk type default.
5. Specifies the IOPS value without any qualifiers. For example, if you require 7,000 IOPS, specify "7000". If you do not specify a value, the capacity is based upon the disk type default.
6. If using storage pools, specify a list of specific storage pools that you want to use in the format: projects/PROJECT_ID/zones/ZONE/storagePools/STORAGE_POOL_NAME.
7. If using storage pools, set **allowedTopologies** to restrict the topology of provisioned volumes to where the storage pool exists. In this example, **us-east4-c**.

3. Create a persistent volume claim (PVC) that uses the hyperdisk-specific storage class using the following example YAML file:

Example PVC YAML file

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: my-pvc
spec:
  storageClassName: hyperdisk-sc 1
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 2048Gi 2
```

1. PVC references the the storage pool-specific storage class. In this example, **hyperdisk-sc**.
2. Target storage capacity of the hyperdisk-balanced volume. In this example, **2048Gi**.

4. Create a deployment that uses the PVC that you just created. Using a deployment helps ensure that your application has access to the persistent storage even after the pod restarts and rescheduling:

   a. Ensure a node pool with the specified machine series is up and running before creating the deployment. Otherwise, the pod fails to schedule.

b. Use the following example YAML file to create the deployment:

Example deployment YAML file

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: postgres
spec:
  selector:
    matchLabels:
      app: postgres
  template:
    metadata:
      labels:
        app: postgres
    spec:
      nodeSelector:
        cloud.google.com/machine-family: n4 (1)
      containers:
      - name: postgres
        image: postgres:14-alpine
        args: [ "sleep", "3600" ]
        volumeMounts:
        - name: sdk-volume
          mountPath: /usr/share/data/
      volumes:
      - name: sdk-volume
        persistentVolumeClaim:
          claimName: my-pvc (2)
```

(1) Specifies the machine family. In this example, it is **n4**.

(2) Specifies the name of the PVC created in the preceding step. In this example, it is **my-pfc**.

c. Confirm that the deployment was successfully created by running the following command:

```
$ oc get deployment
```

Example output

```
NAME       READY   UP-TO-DATE   AVAILABLE   AGE
postgres   0/1     1            0           42s
```

It might take a few minutes for hyperdisk instances to complete provisioning and display a READY status.

d. Confirm that PVC **my-pvc** has been successfully bound to a persistent volume (PV) by running the following command:

```
$ oc get pvc my-pvc
```

Example output

```
NAME          STATUS   VOLUME                                     CAPACITY   ACCESS MODES
STORAGECLASS      VOLUMEATTRIBUTESCLASS  AGE
my-pvc        Bound    pvc-1ff52479-4c81-4481-aa1d-b21c8f8860c6   2Ti        RWO
hyperdisk-sc      <unset>                2m24s
```

e. Confirm the expected configuration of your hyperdisk-balanced disk:

```
$ gcloud compute disks list
```

Example output

```
NAME                                    LOCATION       LOCATION_SCOPE  SIZE_GB  TYPE
STATUS
instance-20240914-173145-boot           us-central1-a  zone            150      pd-standard
READY
instance-20240914-173145-data-workspace  us-central1-a  zone           100      pd-
balanced        READY
c4a-rhel-vm                             us-central1-a  zone            50       hyperdisk-balanced
READY (1)
```

(1) Hyperdisk-balanced disk.

f. If using storage pools, check that the volume is provisioned as specified in your storage class and PVC by running the following command:

```
$ gcloud compute storage-pools list-disks pool-us-east4-c --zone=us-east4-c
```

Example output

```
NAME                                    STATUS  PROVISIONED_IOPS
PROVISIONED_THROUGHPUT  SIZE_GB
pvc-1ff52479-4c81-4481-aa1d-b21c8f8860c6  READY   3000             140
2048
```

5.13.2.4. Additional resources

- Installing a cluster on GCP with customizations

5.13.3. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.13.4. GCP PD CSI driver storage class parameters

The Google Cloud Platform (GCP) persistent disk (PD) Container Storage Interface (CSI) driver uses the CSI **external-provisioner** sidecar as a controller. This is a separate helper container that is deployed with the CSI driver. The sidecar manages persistent volumes (PVs) by triggering the **CreateVolume** operation.

The GCP PD CSI driver uses the **csi.storage.k8s.io/fstype** parameter key to support dynamic provisioning. The following table describes all the GCP PD CSI storage class parameters that are supported by OpenShift Container Platform.

Table 5.5. CreateVolume Parameters

Parameter	Values	Default	Description
type	**pd-ssd**, **pd-standard**, or **pd-balanced**	**pd-standard**	Allows you to choose between standard PVs or solid-state-drive PVs. The driver does not validate the value, thus all the possible values are accepted.
replication-type	**none** or **regional-pd**	**none**	Allows you to choose between zonal or regional PVs.
disk-encryption-kms-key	Fully qualified resource identifier for the key to use to encrypt new disks.	Empty string	Uses customer-managed encryption keys (CMEK) to encrypt new disks.

5.13.5. Creating a custom-encrypted persistent volume

When you create a **PersistentVolumeClaim** object, OpenShift Container Platform provisions a new persistent volume (PV) and creates a **PersistentVolume** object. You can add a custom encryption key in Google Cloud Platform (GCP) to protect a PV in your cluster by encrypting the newly created PV.

For encryption, the newly attached PV that you create uses customer-managed encryption keys (CMEK) on a cluster by using a new or existing Google Cloud Key Management Service (KMS) key.

Prerequisites

- You are logged in to a running OpenShift Container Platform cluster.
- You have created a Cloud KMS key ring and key version.

For more information about CMEK and Cloud KMS resources, see Using customer-managed encryption keys (CMEK).

Procedure

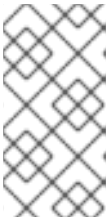
To create a custom-encrypted PV, complete the following steps:

1. Create a storage class with the Cloud KMS key. The following example enables dynamic provisioning of encrypted volumes:

```
apiVersion: storage.k8s.io/v1
```

```
kind: StorageClass
metadata:
  name: csi-gce-pd-cmek
provisioner: pd.csi.storage.gke.io
volumeBindingMode: "WaitForFirstConsumer"
allowVolumeExpansion: true
parameters:
  type: pd-standard
  disk-encryption-kms-key: projects/<key-project-id>/locations/<location>/keyRings/<key-ring>/cryptoKeys/<key> (1)
```

(1) This field must be the resource identifier for the key that will be used to encrypt new disks. Values are case-sensitive. For more information about providing key ID values, see Retrieving a resource's ID and Getting a Cloud KMS resource ID .



NOTE

You cannot add the **disk-encryption-kms-key** parameter to an existing storage class. However, you can delete the storage class and recreate it with the same name and a different set of parameters. If you do this, the provisioner of the existing class must be **pd.csi.storage.gke.io**.

2. Deploy the storage class on your OpenShift Container Platform cluster using the **oc** command:

```
$ oc describe storageclass csi-gce-pd-cmek
```

Example output

```
Name:                  csi-gce-pd-cmek
IsDefaultClass:        No
Annotations:           None
Provisioner:           pd.csi.storage.gke.io
Parameters:            disk-encryption-kms-key=projects/key-project-id/locations/location/keyRings/ring-name/cryptoKeys/key-name,type=pd-standard
AllowVolumeExpansion:  true
MountOptions:          none
ReclaimPolicy:         Delete
VolumeBindingMode:     WaitForFirstConsumer
Events:                none
```

3. Create a file named **pvc.yaml** that matches the name of your storage class object that you created in the previous step:

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: podpvc
spec:
  accessModes:
    - ReadWriteOnce
  storageClassName: csi-gce-pd-cmek
```

```
  resources:
    requests:
      storage: 6Gi
```

NOTE

If you marked the new storage class as default, you can omit the **storageClassName** field.

4. Apply the PVC on your cluster:

```
$ oc apply -f pvc.yaml
```

5. Get the status of your PVC and verify that it is created and bound to a newly provisioned PV:

```
$ oc get pvc
```

Example output

```
NAME     STATUS    VOLUME                                     CAPACITY   ACCESS MODES
STORAGECLASS    AGE
podpvc   Bound     pvc-e36abf50-84f3-11e8-8538-42010a800002   10Gi       RWO           csi-
gce-pd-cmek  9s
```

NOTE

If your storage class has the **volumeBindingMode** field set to **WaitForFirstConsumer**, you must create a pod to use the PVC before you can verify it.

Your CMEK-protected PV is now ready to use with your OpenShift Container Platform cluster.

5.13.6. User-managed encryption

The user-managed encryption feature allows you to provide keys during installation that encrypt OpenShift Container Platform node root volumes, and enables all managed storage classes to use these keys to encrypt provisioned storage volumes. You must specify the custom key in the **platform.<cloud_type>.defaultMachinePlatform** field in the install-config YAML file.

This features supports the following storage types:

- Amazon Web Services (AWS) Elastic Block storage (EBS)
- Microsoft Azure Disk storage
- Google Cloud Platform (GCP) persistent disk (PD) storage
- IBM Virtual Private Cloud (VPC) Block storage

For information about installing with user-managed encryption for GCP PD, see Installation configuration parameters.

5.13.7. Additional resources

- Persistent storage using GCE Persistent Disk
- Configuring CSI volumes

5.14. GOOGLE COMPUTE PLATFORM FILESTORE CSI DRIVER OPERATOR

5.14.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for Google Compute Platform (GCP) Filestore Storage.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

To create CSI-provisioned PVs that mount to GCP Filestore Storage assets, you install the GCP Filestore CSI Driver Operator and the GCP Filestore CSI driver in the **openshift-cluster-csi-drivers** namespace.

- The *GCP Filestore CSI Driver Operator* does not provide a storage class by default, but you can create one if needed. The GCP Filestore CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on demand, eliminating the need for cluster administrators to pre-provision storage.
- The *GCP Filestore CSI driver* enables you to create and mount GCP Filestore PVs.

OpenShift Container Platform GCP Filestore supports Workload Identity. This allows users to access Google Cloud resources using federated identities instead of a service account key. GCP Workload Identity must be enabled globally during installation, and then configured for the GCP Filestore CSI Driver Operator. For more information, see Installing the GCP Filestore CSI Driver Operator .

5.14.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.14.3. Installing the GCP Filestore CSI Driver Operator

5.14.3.1. Preparing to install the GCP Filestore CSI Driver Operator with Workload Identity

If you are planning to use GCP Workload Identity with Google Compute Platform Filestore, you must obtain certain parameters that you will use during the installation of the GCP Filestore Container Storage Interface (CSI) Driver Operator.

Prerequisites

- Access to the cluster as a user with the cluster-admin role.

Procedure

To prepare to install the GCP Filestore CSI Driver Operator with Workload Identity:

1. Obtain the project number:

   a. Obtain the project ID by running the following command:

   ```
   $ export PROJECT_ID=$(oc get infrastructure/cluster -o
   jsonpath='{.status.platformStatus.gcp.projectID}')
   ```

   b. Obtain the project number, using the project ID, by running the following command:

   ```
   $ gcloud projects describe $PROJECT_ID --format="value(projectNumber)"
   ```

2. Find the identity pool ID and the provider ID:
   During cluster installation, the names of these resources are provided to the Cloud Credential Operator utility (**ccoctl**) with the **--name parameter**. See "Creating GCP resources with the Cloud Credential Operator utility".

3. Create Workload Identity resources for the GCP Filestore Operator:

   a. Create a **CredentialsRequest** file using the following example file:

   #### Example Credentials Request YAML file

   ```
   apiVersion: cloudcredential.openshift.io/v1
   kind: CredentialsRequest
   metadata:
     name: openshift-gcp-filestore-csi-driver-operator
     namespace: openshift-cloud-credential-operator
     annotations:
       include.release.openshift.io/self-managed-high-availability: "true"
       include.release.openshift.io/single-node-developer: "true"
   spec:
     serviceAccountNames:
     - gcp-filestore-csi-driver-operator
     - gcp-filestore-csi-driver-controller-sa
     secretRef:
       name: gcp-filestore-cloud-credentials
       namespace: openshift-cluster-csi-drivers
     providerSpec:
       apiVersion: cloudcredential.openshift.io/v1
    kind: GCPProviderSpec
       predefinedRoles:
       - roles/file.editor
       - roles/resourcemanager.tagUser
       skipServiceCheck: true
   ```

   b. Use the **CredentialsRequest** file to create a GCP service account by running the following command:

   ```
   $ ./ccoctl gcp create-service-accounts --name=<filestore-service-account> \ 1
     --workload-identity-pool=<workload-identity-pool> \ 2
     --workload-identity-provider=<workload-identity-provider> \ 3
   ```

```
--project=<project-id> \ 4
--credentials-requests-dir=/tmp/credreq 5
```

1. <filestore-service-account> is a user-chosen name.
2. <workload-identity-pool> comes from Step 2 above.
3. <workload-identity-provider> comes from Step 2 above.
4. <project-id> comes from Step 1.a above.
5. The name of directory where the **CredentialsRequest** file resides.

Example output

```
2025/02/10 17:47:39 Credentials loaded from gcloud CLI defaults
2025/02/10 17:47:42 IAM service account filestore-service-account-openshift-gcp-filestore-csi-driver-operator created
2025/02/10 17:47:44 Unable to add predefined roles to IAM service account, retrying...
2025/02/10 17:47:59 Updated policy bindings for IAM service account filestore-service-account-openshift-gcp-filestore-csi-driver-operator
2025/02/10 17:47:59 Saved credentials configuration to: /tmp/install-dir/ 1
openshift-cluster-csi-drivers-gcp-filestore-cloud-credentials-credentials.yaml
```

1. The current directory.

c. Find the service account email of the newly created service account by running the following command:

```
$ cat /tmp/install-dir/manifests/openshift-cluster-csi-drivers-gcp-filestore-cloud-credentials-credentials.yaml | yq '.data["service_account.json"]' | base64 -d | jq '.service_account_impersonation_url'
```

Example output

```
https://iamcredentials.googleapis.com/v1/projects/-/serviceAccounts/filestore-se-openshift-g-ch8cm@openshift-gce-devel.iam.gserviceaccount.com:generateAccessToken
```

In this example output, the service account email is **filestore-se-openshift-g-ch8cm@openshift-gce-devel.iam.gserviceaccount.com**.

Results

You now have the following parameters that you need to install the GCP Filestore CSI Driver Operator:

- Project number - from Step 1.b
- Pool ID - from Step 2
- Provider ID - from Step 2
- Service account email - from Step 3.c

Additional resources

- Creating GCP resources with the Cloud Credential Operator utility

5.14.3.2. Installing the GCP Filestore CSI Driver Operator

The Google Compute Platform (GCP) Filestore Container Storage Interface (CSI) Driver Operator is not installed in OpenShift Container Platform by default. Use the following procedure to install the GCP Filestore CSI Driver Operator in your cluster.

Prerequisites

- Access to the OpenShift Container Platform web console.
- If using GCP Workload Identity, certain GCP Workload Identity parameters are needed. See the preceding Section *Preparing to install the GCP Filestore CSI Driver Operator with Workload Identity*.

Procedure

To install the GCP Filestore CSI Driver Operator from the web console:

1. Log in to the web console.
2. Enable the Filestore API in the GCE project by running the following command:

```
$ gcloud services enable file.googleapis.com  --project <my_gce_project>
```
(1)

(1) Replace **<my_gce_project>** with your Google Cloud project.

   You can also do this using Google Cloud web console.

3. Install the GCP Filestore CSI Operator:
   a. Click **Operators → OperatorHub**.
   b. Locate the GCP Filestore CSI Operator by typing **GCP Filestore** in the filter box.
   c. Click the **GCP Filestore CSI Driver Operator** button.
   d. On the **GCP Filestore CSI Driver Operator** page, click **Install**.
   e. On the **Install Operator** page, ensure that:
      - **All namespaces on the cluster (default)** is selected.
      - **Installed Namespace** is set to **openshift-cluster-csi-drivers**.
        If using GCP Workload Identity, enter values for the following fields obtained from the procedure in Section *Preparing to install the GCP Filestore CSI Driver Operator with Workload Identity*:
      - **GCP Project Number**
      - **GCP Pool ID**
      - **GCP Provider ID**

- **GCP Service Account Email**

f. Click **Install**.
After the installation finishes, the GCP Filestore CSI Operator is listed in the **Installed Operators** section of the web console.

4. Install the GCP Filestore CSI Driver:

a. Click **administration → CustomResourceDefinitions → ClusterCSIDriver**.

b. On the **Instances** tab, click **Create ClusterCSIDriver**.
Use the following YAML file:

```
apiVersion: operator.openshift.io/v1
kind: ClusterCSIDriver
metadata:
    name: filestore.csi.storage.gke.io
spec:
  managementState: Managed
```

c. Click **Create**.

d. Wait for the following Conditions to change to a "true" status:

- GCPFilestoreDriverCredentialsRequestControllerAvailable
- GCPFilestoreDriverNodeServiceControllerAvailable
- GCPFilestoreDriverControllerServiceControllerAvailable

Additional resources

- Enabling an API in your Google Cloud .
- Enabling an API using the Google Cloud web console .

5.14.4. Creating a storage class for GCP Filestore Storage

After installing the Operator, you should create a storage class for dynamic provisioning of Google Compute Platform (GCP) Filestore volumes.

Prerequisites

- You are logged in to the running OpenShift Container Platform cluster.

Procedure

To create a storage class:

1. Create a storage class using the following example YAML file:

Example YAML file

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
```

```
  name: filestore-csi
provisioner: filestore.csi.storage.gke.io
parameters:
  connect-mode: DIRECT_PEERING (1)
  network: network-name (2)
allowVolumeExpansion: true
volumeBindingMode: WaitForFirstConsumer
```

(1) For a shared VPC, use the **connect-mode** parameter set to **PRIVATE_SERVICE_ACCESS**. For a non-shared VPC, the value is **DIRECT_PEERING**, which is the default setting.

(2) Specify the name of the GCP virtual private cloud (VPC) network where Filestore instances should be created in.

2. Specify the name of the VPC network where Filestore instances should be created in.
It is recommended to specify the VPC network that the Filestore instances should be created in. If no VPC network is specified, the Container Storage Interface (CSI) driver tries to create the instances in the default VPC network of the project.

   On IPI installations, the VPC network name is typically the cluster name with the suffix "-network". However, on UPI installations, the VPC network name can be any value chosen by the user.

   For a shared VPC (**connect-mode** = **PRIVATE_SERVICE_ACCESS**), the network needs to be the full VPC name. For example: **projects/shared-vpc-name/global/networks/gcp-filestore-network**.

   You can find out the VPC network name by inspecting the **MachineSets** objects with the following command:

```
$ oc -n openshift-machine-api get machinesets -o yaml | grep "network:"
          - network: gcp-filestore-network
(...)
```

   In this example, the VPC network name in this cluster is "gcp-filestore-network".

5.14.5. Destroying clusters and GCP Filestore

Typically, if you destroy a cluster, the OpenShift Container Platform installer deletes all of the cloud resources that belong to that cluster. However, due to the special nature of the Google Compute Platform (GCP) Filestore resources, the automated cleanup process might not remove all of them in some rare cases.

Therefore, Red Hat recommends that you verify that all cluster-owned Filestore resources are deleted by the uninstall process.

Procedure

To ensure that all GCP Filestore PVCs have been deleted:

1. Access your Google Cloud account using the GUI or CLI.
2. Search for any resources with the **kubernetes-io-cluster-${CLUSTER_ID}=owned** label.

Since the cluster ID is unique to the deleted cluster, there should not be any remaining resources with that cluster ID.

3. In the unlikely case there are some remaining resources, delete them.

5.14.6. Additional resources

- Configuring CSI volumes
- CCO-based workflow for OLM-managed Operators with GCP Workload Identity .

5.15. IBM CLOUD VPC BLOCK CSI DRIVER OPERATOR

5.15.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for IBM® Virtual Private Cloud (VPC) Block Storage.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

To create CSI-provisioned PVs that mount to IBM Cloud® VPC Block storage assets, OpenShift Container Platform installs the IBM Cloud® VPC Block CSI Driver Operator and the IBM Cloud® VPC Block CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- The *IBM Cloud® VPC Block CSI Driver Operator* provides three storage classes named **ibmc-vpc-block-10iops-tier** (default), **ibmc-vpc-block-5iops-tier**, and **ibmc-vpc-block-custom** for different tiers that you can use to create persistent volume claims (PVCs). The IBM Cloud® VPC Block CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on demand, eliminating the need for cluster administrators to pre-provision storage. You can disable this default storage class if desired (see Managing the default storage class).
- The *IBM Cloud® VPC Block CSI driver* enables you to create and mount IBM Cloud® VPC Block PVs.

5.15.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.15.3. User-managed encryption

The user-managed encryption feature allows you to provide keys during installation that encrypt OpenShift Container Platform node root volumes, and enables all managed storage classes to use these keys to encrypt provisioned storage volumes. You must specify the custom key in the **platform.<cloud_type>.defaultMachinePlatform** field in the install-config YAML file.

This features supports the following storage types:

- Amazon Web Services (AWS) Elastic Block storage (EBS)

- Microsoft Azure Disk storage
- Google Cloud Platform (GCP) persistent disk (PD) storage
- IBM Virtual Private Cloud (VPC) Block storage

For information about installing with user-managed encryption for IBM Cloud, see User-managed encryption for IBM Cloud and Preparing to install on IBM Cloud .

Additional resources

- Configuring CSI volumes

5.16. IBM POWER VIRTUAL SERVER BLOCK CSI DRIVER OPERATOR

5.16.1. Introduction

The IBM Power® Virtual Server Block CSI Driver is installed through the IBM Power® Virtual Server Block CSI Driver Operator and the operator is based on **library-go**. The OpenShift Container Platform **library-go** framework is a collection of functions that allows users to build OpenShift operators easily. Most of the functionality of a CSI Driver Operator is already available there. The IBM Power® Virtual Server Block CSI Driver Operator is installed by the Cluster Storage Operator. The Cluster Storage Operator installs the IBM Power® Virtual Server Block CSI Driver Operator if the platform type is Power Virtual Servers.

5.16.2. Overview

OpenShift Container Platform can provision persistent volumes (PVs) by using the Container Storage Interface (CSI) driver for IBM Power® Virtual Server Block Storage.

Familiarity with persistent storage and configuring CSI volumes is helpful when working with a CSI Operator and driver.

To create CSI-provisioned PVs that mount to IBM Power® Virtual Server Block storage assets, OpenShift Container Platform installs the IBM Power® Virtual Server Block CSI Driver Operator and the IBM Power® Virtual Server Block CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- The *IBM Power® Virtual Server Block CSI Driver Operator* provides two storage classes named **ibm-powervs-tier1** (default), and **ibm-powervs-tier3** for different tiers that you can use to create persistent volume claims (PVCs). The IBM Power® Virtual Server Block CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on demand, eliminating the need for cluster administrators to pre-provision storage.
- The *IBM Power® Virtual Server Block CSI driver* allows you to create and mount IBM Power® Virtual Server Block PVs.

5.16.3. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

Additional resources

- Configuring CSI volumes

5.17. OPENSTACK CINDER CSI DRIVER OPERATOR

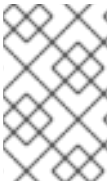
5.17.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for OpenStack Cinder.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a Container Storage Interface (CSI) Operator and driver.

To create CSI-provisioned PVs that mount to OpenStack Cinder storage assets, OpenShift Container Platform installs the OpenStack Cinder CSI Driver Operator and the OpenStack Cinder CSI driver in the **openshift-cluster-csi-drivers** namespace.

- The *OpenStack Cinder CSI Driver Operator* provides a CSI storage class that you can use to create PVCs. You can disable this default storage class if desired (see Managing the default storage class).
- The *OpenStack Cinder CSI driver* enables you to create and mount OpenStack Cinder PVs.



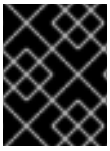
NOTE

OpenShift Container Platform provides automatic migration for the Cinder in-tree volume plugin to its equivalent CSI driver. For more information, see CSI automatic migration.

5.17.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.



IMPORTANT

OpenShift Container Platform defaults to using the CSI plugin to provision Cinder storage.

5.17.3. Making OpenStack Cinder CSI the default storage class

The OpenStack Cinder CSI driver uses the **cinder.csi.openstack.org** parameter key to support dynamic provisioning.

To enable OpenStack Cinder CSI provisioning in OpenShift Container Platform, it is recommended that you overwrite the default in-tree storage class with **standard-csi**. Alternatively, you can create the persistent volume claim (PVC) and specify the storage class as "standard-csi".

In OpenShift Container Platform, the default storage class references the in-tree Cinder driver. However, with CSI automatic migration enabled, volumes created using the default storage class actually use the CSI driver.

Procedure

Use the following steps to apply the **standard-csi** storage class by overwriting the default in-tree storage class.

1. List the storage class:

```
$ oc get storageclass
```

Example output

```
NAME                 PROVISIONER                RECLAIMPOLICY   VOLUMEBINDINGMODE
ALLOWVOLUMEEXPANSION   AGE
standard(default)    cinder.csi.openstack.org   Delete          WaitForFirstConsumer   true
46h
standard-csi         kubernetes.io/cinder       Delete          WaitForFirstConsumer   true
46h
```

2. Change the value of the annotation **storageclass.kubernetes.io/is-default-class** to **false** for the default storage class, as shown in the following example:

```
$ oc patch storageclass standard -p '{"metadata": {"annotations":
{"storageclass.kubernetes.io/is-default-class": "false"}}}'
```

3. Make another storage class the default by adding or modifying the annotation as **storageclass.kubernetes.io/is-default-class=true**.

```
$ oc patch storageclass standard-csi -p '{"metadata": {"annotations":
{"storageclass.kubernetes.io/is-default-class": "true"}}}'
```

4. Verify that the PVC is now referencing the CSI storage class by default:

```
$ oc get storageclass
```

Example output

```
NAME                 PROVISIONER                RECLAIMPOLICY   VOLUMEBINDINGMODE
ALLOWVOLUMEEXPANSION   AGE
standard             kubernetes.io/cinder       Delete          WaitForFirstConsumer   true
46h
standard-csi(default)  cinder.csi.openstack.org   Delete          WaitForFirstConsumer   true
46h
```

5. Optional: You can define a new PVC without having to specify the storage class:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: cinder-claim
spec:
```

```
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
```

A PVC that does not specify a specific storage class is automatically provisioned by using the default storage class.

6. Optional: After the new file has been configured, create it in your cluster:

```
$ oc create -f cinder-claim.yaml
```

Additional resources

- Configuring CSI volumes

5.18. OPENSTACK MANILA CSI DRIVER OPERATOR

5.18.1. Overview

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) using the Container Storage Interface (CSI) driver for the OpenStack Manila shared file system service.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a Container Storage Interface (CSI) Operator and driver.

To create CSI-provisioned PVs that mount to Manila storage assets, OpenShift Container Platform installs the Manila CSI Driver Operator and the Manila CSI driver by default on any OpenStack cluster that has the Manila service enabled.

- The *Manila CSI Driver Operator* creates the required storage class that is needed to create PVCs for all available Manila share types. The Operator is installed in the **openshift-cluster-csi-drivers** namespace.
- The *Manila CSI driver* enables you to create and mount Manila PVs. The driver is installed in the **openshift-manila-csi-driver** namespace.

5.18.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.18.3. Manila CSI Driver Operator limitations

The following limitations apply to the Manila Container Storage Interface (CSI) Driver Operator:

Only NFS is supported

OpenStack Manila supports many network-attached storage protocols, such as NFS, CIFS, and CEPHFS, and these can be selectively enabled in the OpenStack cloud. The Manila CSI Driver

Operator in OpenShift Container Platform only supports using the NFS protocol. If NFS is not available and enabled in the underlying OpenStack cloud, you cannot use the Manila CSI Driver Operator to provision storage for OpenShift Container Platform.

Snapshots are not supported if the back end is CephFS-NFS

To take snapshots of persistent volumes (PVs) and revert volumes to snapshots, you must ensure that the Manila share type that you are using supports these features. A Red Hat OpenStack administrator must enable support for snapshots (**share type extra-spec snapshot_support**) and for creating shares from snapshots (**share type extra-spec create_share_from_snapshot_support**) in the share type associated with the storage class you intend to use.

FSGroups are not supported

Since Manila CSI provides shared file systems for access by multiple readers and multiple writers, it does not support the use of FSGroups. This is true even for persistent volumes created with the ReadWriteOnce access mode. It is therefore important not to specify the **fsType** attribute in any storage class that you manually create for use with Manila CSI Driver.

IMPORTANT

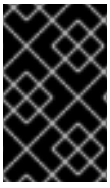
In Red Hat OpenStack Platform 16.x and 17.x, the Shared File Systems service (Manila) with CephFS through NFS fully supports serving shares to OpenShift Container Platform through the Manila CSI. However, this solution is not intended for massive scale. Be sure to review important recommendations in CephFS NFS Manila-CSI Workload Recommendations for Red Hat OpenStack Platform.

5.18.4. Dynamically provisioning Manila CSI volumes

OpenShift Container Platform installs a storage class for each available Manila share type.

The YAML files that are created are completely decoupled from Manila and from its Container Storage Interface (CSI) plugin. As an application developer, you can dynamically provision ReadWriteMany (RWX) storage and deploy pods with applications that safely consume the storage using YAML manifests.

You can use the same pod and persistent volume claim (PVC) definitions on-premise that you use with OpenShift Container Platform on AWS, GCP, Azure, and other platforms, with the exception of the storage class reference in the PVC definition.



IMPORTANT

By default the access-rule assigned to a volume is set to 0.0.0.0/0. To limit the clients that can mount the persistent volume (PV), create a new storage class with an IP or a subnet mask in the **nfs-shareClient** storage class parameter.

NOTE

Manila service is optional. If the service is not enabled in Red Hat OpenStack Platform (RHOSP), the Manila CSI driver is not installed and the storage classes for Manila are not created.

Prerequisites

- RHOSP is deployed with appropriate Manila share infrastructure so that it can be used to dynamically provision and mount volumes in OpenShift Container Platform.

Procedure (UI)

To dynamically create a Manila CSI volume using the web console:

1. In the OpenShift Container Platform console, click **Storage → Persistent Volume Claims**
2. In the persistent volume claims overview, click **Create Persistent Volume Claim**
3. Define the required options on the resulting page.
   a. Select the appropriate storage class.
   b. Enter a unique name for the storage claim.
   c. Select the access mode to specify read and write access for the PVC you are creating.

IMPORTANT

Use RWX if you want the PV that fulfills this PVC to be mounted to multiple pods on multiple nodes in the cluster.

4. Define the size of the storage claim.
5. Click **Create** to create the PVC and generate a PV.

Procedure (CLI)

To dynamically create a Manila CSI volume using the command-line interface (CLI):

1. Create and save a file with the **PersistentVolumeClaim** object described by the following YAML:

pvc-manila.yaml

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc-manila
spec:
  accessModes: 1
    - ReadWriteMany
  resources:
    requests:
      storage: 10Gi
  storageClassName: csi-manila-gold 2
```

1 Use RWX if you want the PV that fulfills this PVC to be mounted to multiple pods on multiple nodes in the cluster.

2 The name of the storage class that provisions the storage back end. Manila storage classes are provisioned by the Operator and have the **csi-manila-** prefix.

2. Create the object you saved in the previous step by running the following command:

```
$ oc create -f pvc-manila.yaml
```

A new PVC is created.

3. To verify that the volume was created and is ready, run the following command:

```
$ oc get pvc pvc-manila
```

The **pvc-manila** shows that it is **Bound**.

You can now use the new PVC to configure a pod.

Additional resources

- Configuring CSI volumes

5.19. SECRETS STORE CSI DRIVER

5.19.1. Overview

Kubernetes secrets are stored with Base64 encoding. etcd provides encryption at rest for these secrets, but when secrets are retrieved, they are decrypted and presented to the user. If role-based access control is not configured properly on your cluster, anyone with API or etcd access can retrieve or modify a secret. Additionally, anyone who is authorized to create a pod in a namespace can use that access to read any secret in that namespace.

To store and manage your secrets securely, you can configure the OpenShift Container Platform Secrets Store Container Storage Interface (CSI) Driver Operator to mount secrets from an external secret management system, such as Azure Key Vault, by using a provider plugin. Applications can then use the secret, but the secret does not persist on the system after the application pod is destroyed.

The Secrets Store CSI Driver Operator, **secrets-store.csi.k8s.io**, enables OpenShift Container Platform to mount multiple secrets, keys, and certificates stored in enterprise-grade external secrets stores into pods as a volume. The Secrets Store CSI Driver Operator communicates with the provider using gRPC to fetch the mount contents from the specified external secrets store. After the volume is attached, the data in it is mounted into the container's file system. Secrets store volumes are mounted in-line.

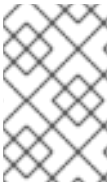
For more information about CSI inline volumes, see CSI inline ephemeral volumes .

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI driver.

5.19.1.1. Secrets store providers

The Secrets Store CSI Driver Operator has been tested with the following secrets store providers:

- AWS Secrets Manager
- AWS Systems Manager Parameter Store
- Azure Key Vault
- Google Secret Manager
- HashiCorp Vault



NOTE

Red Hat does not test all factors associated with third-party secrets store provider functionality. For more information about third-party support, see the Red Hat third-party support policy.

5.19.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.19.3. Installing the Secrets Store CSI driver

Prerequisites

- Access to the OpenShift Container Platform web console.
- Administrator access to the cluster.

Procedure

To install the Secrets Store CSI driver:

1. Install the Secrets Store CSI Driver Operator:
   a. Log in to the web console.
   b. Click **Operators → OperatorHub**.
   c. Locate the Secrets Store CSI Driver Operator by typing "Secrets Store CSI" in the filter box.
   d. Click the **Secrets Store CSI Driver Operator** button.
   e. On the **Secrets Store CSI Driver Operator** page, click **Install**.
   f. On the **Install Operator** page, ensure that:
      - **All namespaces on the cluster (default)** is selected.
      - **Installed Namespace** is set to **openshift-cluster-csi-drivers**.
   g. Click **Install**.
   After the installation finishes, the Secrets Store CSI Driver Operator is listed in the **Installed Operators** section of the web console.
2. Create the **ClusterCSIDriver** instance for the driver (**secrets-store.csi.k8s.io**):
   a. Click **Administration → CustomResourceDefinitions → ClusterCSIDriver**.
   b. On the **Instances** tab, click **Create ClusterCSIDriver**.
   Use the following YAML file:

```
apiVersion: operator.openshift.io/v1
```

```
kind: ClusterCSIDriver
metadata:
   name: secrets-store.csi.k8s.io
spec:
  managementState: Managed
```

c. Click **Create**.

Next steps

- Mounting secrets from an external secrets store to a CSI volume

5.19.4. Uninstalling the Secrets Store CSI Driver Operator

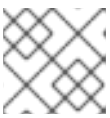
Prerequisites

- Access to the OpenShift Container Platform web console.
- Administrator access to the cluster.

Procedure

To uninstall the Secrets Store CSI Driver Operator:

1. Stop all application pods that use the **secrets-store.csi.k8s.io** provider.
2. Remove any third-party provider plug-in for your chosen secret store.
3. Remove the Container Storage Interface (CSI) driver and associated manifests:
   a. Click **Administration → CustomResourceDefinitions → ClusterCSIDriver**.
   b. On the **Instances** tab, for **secrets-store.csi.k8s.io**, on the far left side, click the drop-down menu, and then click **Delete ClusterCSIDriver**.
   c. When prompted, click **Delete**.
4. Verify that the CSI driver pods are no longer running.
5. Uninstall the Secrets Store CSI Driver Operator:



NOTE

Before you can uninstall the Operator, you must remove the CSI driver first.

   a. Click **Operators → Installed Operators**.
   b. On the **Installed Operators** page, scroll or type "Secrets Store CSI" into the **Search by name** box to find the Operator, and then click it.
   c. On the upper, right of the **Installed Operators** > **Operator details** page, click **Actions → Uninstall Operator**.
   d. When prompted on the **Uninstall Operator** window, click the **Uninstall** button to remove the Operator from the namespace. Any applications deployed by the Operator on the cluster need to be cleaned up manually.

After uninstalling, the Secrets Store CSI Driver Operator is no longer listed in the **Installed Operators** section of the web console.

5.19.5. Additional resources

- Configuring CSI volumes

5.20. CIFS/SMB CSI DRIVER OPERATOR

OpenShift Container Platform is capable of provisioning persistent volumes (PVs) with a Container Storage Interface (CSI) driver for Common Internet File System (CIFS) dialect/Server Message Block (SMB) protocol.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

After installing the CIFS/SMB CSI Driver Operator, OpenShift Container Platform installs corresponding pods for the Operator and driver in the **openshift-cluster-csi-drivers** namespace by default. This allows the CIFS/SMB CSI Driver to create CSI-provisioned persistent volumes (PVs) that mount to CIFS/SMB shares.

- The *CIFS/SMB CSI Driver Operator*, after being installed, does not create a storage class by default to use to create persistent volume claims (PVCs). However, you can manually create the CIFS/SMB **StorageClass** for dynamic provisioning. The CIFS/SMB CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on-demand. This eliminates the need for cluster administrators to pre-provision storage.

- The *CIFS/SMB CSI driver* enables you to create and mount CIFS/SMB PVs.

5.20.1. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.20.2. Limitations

The following limitations apply to the Common Internet File System (CIFS)/Server Message Block (SMB) Container Storage Interface (CSI) Driver Operator:

- FIPS mode is not supported:
  When Federal Information Processing Standards (FIPS) mode is enabled, the use of md4 and md5 are disabled, which prevents users from using ntlm, ntlmv2, or ntlmssp authentication. Also, signing cannot be used because it uses md5. Any CIFS mount that uses these methods fails when FIPS mode is enabled.

- Using HTTP proxy configuration to connect to outside of the cluster SMB servers is not supported by the CSI driver.
  Since CIFS/SMB is a LAN protocol, and though it can be routed to subnets, it is not designed to be extended over the WAN, and does not support HTTP proxy settings.

- The CIFS/SMB CSI Driver Operator does *not* support Windows Distributed File System (DFS).

- Kerberos authentication is not supported.
- SMB CSI was tested with Samba v4.21.2 and Windows Server 2019 and Windows Server 2022.

5.20.3. Installing the CIFS/SMB CSI Driver Operator

The CIFS/SMB CSI Driver Operator (a Red Hat Operator) is not installed in OpenShift Container Platform by default. Use the following procedure to install and configure the CIFS/SMB CSI Driver Operator in your cluster.

Prerequisites

- Access to the OpenShift Container Platform web console.

Procedure

To install the CIFS/SMB CSI Driver Operator from the web console:

1. Log in to the web console.
2. Install the CIFS/SMB CSI Operator:
   a. Click **Operators → OperatorHub**.
   b. Locate the CIFS/SMB CSI Operator by typing **CIFS/SMB CSI** in the filter box.
   c. Click the **CIFS/SMB CSI Driver Operator** button.
   d. On the **CIFS/SMB CSI Driver Operator** page, click **Install**.
   e. On the **Install Operator** page, ensure that:
      - **All namespaces on the cluster (default)**is selected.
      - **Installed Namespace** is set to **openshift-cluster-csi-drivers**.
   f. Click **Install**.
   After the installation finishes, the CIFS/SMB CSI Operator is listed in the **Installed Operators** section of the web console.

5.20.4. Installing the CIFS/SMB CSI Driver

After installing the CIFS/SMB Container Storage Interface (CSI) Driver Operator, install the CIFS/SMB CSI driver.

Prerequisites

- Access to the OpenShift Container Platform web console.
- CIFS/SMB CSI Driver Operator installed.

Procedure

1. Click **Administration → CustomResourceDefinitions → ClusterCSIDriver**.
2. On the **Instances** tab, click **Create ClusterCSIDriver**.

3. Use the following YAML file:

```
apiVersion: operator.openshift.io/v1
kind: ClusterCSIDriver
metadata:
   name: smb.csi.k8s.io
spec:
  managementState: Managed
```

4. Click **Create**.

5. Wait for the following Conditions to change to a "True" status:

   - **SambaDriverControllerServiceControllerAvailable**
   - **SambaDriverNodeServiceControllerAvailable**

5.20.5. Dynamic provisioning

You can create a storage class for dynamic provisioning of Common Internet File System (CIFS) dialect/Server Message Block (SMB) protocol volumes. Provisioning volumes creates a subdirectory with the persistent volume (PV) name under **source** defined in the storage class.

Prerequisites

- CIFS/SMB CSI Driver Operator and driver installed.
- You are logged in to the running OpenShift Container Platform cluster.
- You have installed the SMB server and know the following information about the server:
  - Hostname
  - Share name
  - Username and password

Procedure

To set up dynamic provisioning:

1. Create a Secret for access to the Samba server using the following command with the following example YAML file:

```
$ oc create -f <file_name>.yaml
```

Secret example YAML file

```
apiVersion: v1
kind: Secret
metadata:
  name: smbcreds (1)
  namespace: samba-server (2)
```

```
stringData:
  username: <username> 3
  password: <password> 4
```

1. Name of the Secret for the Samba server.
2. Namespace for the Secret for the Samba server.
3. Username for the Secret for the Samba server.
4. Password for the Secret for the Samba server.

2. Create a storage class by running the following command with the following example YAML file:

```
$ oc create -f <sc_file_name>.yaml 1
```

1. Name of the storage class YAML file.

Storage class example YAML file

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <sc_name> 1
provisioner: smb.csi.k8s.io
parameters:
  source: //<hostname>/<shares> 2
  csi.storage.k8s.io/provisioner-secret-name: smbcreds 3
  csi.storage.k8s.io/provisioner-secret-namespace: samba-server 4
  csi.storage.k8s.io/node-stage-secret-name: smbcreds 5
  csi.storage.k8s.io/node-stage-secret-namespace: samba-server 6
reclaimPolicy: Delete
volumeBindingMode: Immediate
mountOptions:
  - dir_mode=0777
  - file_mode=0777
  - uid=1001
  - gid=1001
```

1. The name of the storage class.
2. The Samba server must be installed somewhere and reachable from the cluster with <`hostname>` being the hostname for the Samba server and **<shares>** the path the server is configured to have among the exported shares.
3. 5 Name of the Secret for the Samba server that was set in the previous step. If the **csi.storage.k8s.io/provisioner-secret** is provided, a subdirectory is created with the PV name under **source**.
4. 6 Namespace for the Secret for the Samba server that was set in the previous step.

3. Create a PVC:

a. Create a PVC by running the following command with the following example YAML file:

```
$ oc create -f <pv_file_name>.yaml 1
```

1 The name of the PVC YAML file.

Example PVC YAML file

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: <pvc_name> 1
spec:
  accessModes:
    - ReadWriteMany
  resources:
    requests:
      storage: <storage_amount> 2
  storageClassName: <sc_name> 3
```

1 The name of the PVC.

2 Storage request amount.

3 The name of the CIFS/SMB storage class that you created in the previous step.

b. Ensure that the PVC was created and is in the "Bound" status by running the following command:

```
$ oc describe pvc <pvc_name> 1
```

1 The name of the PVC that you created in the preceding step.

Example output

```
Name:          pvc-test
Namespace:     default
StorageClass:  samba
Status:        Bound 1
...
```

1 PVC is in Bound status.

5.20.6. Static provisioning

You can use static provisioning to create a persistent volume (PV) and persistent volume claim (PVC) to consume existing Server Message Block protocol (SMB) shares:

Prerequisites

- Access to the OpenShift Container Platform web console.
- CIFS/SMB CSI Driver Operator and driver installed.
- You have installed the SMB server and know the following information about the server:
  - Hostname
  - Share name
  - Username and password

Procedure

To set up static provisioning:

1. Create a Secret for access to the Samba server using the following command with the following example YAML file:

```
$ oc create -f <file_name>.yaml
```

Secret example YAML file

```
apiVersion: v1
kind: Secret
metadata:
  name: smbcreds 1
  namespace: samba-server 2
stringData:
  username: <username> 3
  password: <password> 4
```

1. Name of the Secret for the Samba server.
2. Namespace for the Secret for the Samba server.
3. Username for the Secret for the Samba server.
4. Password for the Secret for the Samba server.

2. Create a PV by running the following command with the following example YAML file:

```
$ oc create -f <pv_file_name>.yaml 1
```

1. The name of the PV YAML file.

Example PV YAML file

```
apiVersion: v1
kind: PersistentVolume
metadata:
  annotations:
    pv.kubernetes.io/provisioned-by: smb.csi.k8s.io
```

```
  name: <pv_name> (1)
spec:
  capacity:
    storage: 100Gi
  accessModes:
    - ReadWriteMany
  persistentVolumeReclaimPolicy: Retain
  storageClassName: ""
  mountOptions:
    - dir_mode=0777
    - file_mode=0777
  csi:
    driver: smb.csi.k8s.io
    volumeHandle: smb-server.default.svc.cluster.local/share# (2)
    volumeAttributes:
      source: //<hostname>/<shares> (3)
    nodeStageSecretRef:
      name: <secret_name_shares> (4)
      namespace: <namespace> (5)
```

(1) The name of the PV.

(2) **volumeHandle** format: {smb-server-address}#{sub-dir-name}#{share-name}. Ensure that this value is unique for every share in the cluster.

(3) The Samba server must be installed somewhere and reachable from the cluster with <hostname> being the hostname for the Samba server and <shares> the path the server is configured to have among the exported shares.

(4) The name of the Secret for the shares.

(5) The applicable namespace.

3. Create a PVC:

   a. Create a PVC by running the following command with the following example YAML file:

```
$ oc create -f <pv_file_name>.yaml (1)
```

(1) The name of the PVC YAML file.

Example PVC YAML file

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: <pvc_name> (1)
spec:
  accessModes:
    - ReadWriteMany
  resources:
    requests:
```

```
    storage: <storage_amount> 2
storageClassName: ""
volumeName: <pv_name> 3
```

1 The name of the PVC.

2 Storage request amount.

3 The name of the PV from the first step.

b. Ensure that the PVC was created and is in the "Bound" status by running the following command:

```
$ oc describe pvc <pvc_name> 1
```

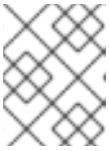
1 The name of the PVC that you created in the preceding step.

Example output

```
Name:         pvc-test
Namespace:    default
StorageClass:
Status:       Bound 1
...
```

1 PVC is in Bound status.

4. Create a deployment on Linux by running the following command with the following example YAML file:



NOTE

The following deployment is not mandatory for using the PV and PVC created in the previous steps. It is example of how they can be used.

```
$ oc create -f <deployment_file_name>.yaml 1
```

1 The name of the deployment YAML file.

Example deployment YAML file

```
apiVersion: apps/v1
kind: Deployment
metadata:
  labels:
    app: nginx
  name: <deployment_name> 1
spec:
  replicas: 1
```

```
  selector:
    matchLabels:
      app: nginx
  template:
    metadata:
      labels:
        app: nginx
      name: <deployment_name> 2
    spec:
      nodeSelector:
        "kubernetes.io/os": linux
      containers:
        - name: <deployment_name> 3
          image: quay.io/centos/centos:stream8
          command:
            - "/bin/bash"
            - "-c"
            - set -euo pipefail; while true; do echo $(date) >> <mount_path>/outfile; sleep 1; done
4
          volumeMounts:
            - name: <vol_mount_name> 5
              mountPath: <mount_path> 6
              readOnly: false
      volumes:
        - name: <vol_mount_name> 7
          persistentVolumeClaim:
            claimName: <pvc_name> 8
  strategy:
    rollingUpdate:
      maxSurge: 0
      maxUnavailable: 1
    type: RollingUpdate
```

1 2 3 The name of the deployment.

4 6 The volume mount path.

5 7 The name of the volume mount.

8 The name of the PVC created in the preceding step.

5. Check the setup by running the **df -h** command in the container:

```
$ oc exec -it <pod_name> -- df -h 1
```

1 The name of the pod.

Example output

```
Filesystem          Size  Used Avail Use% Mounted on
...
/dev/sda1           97G   21G   77G  22% /etc/hosts
```

```
//20.43.191.64/share   97G   21G   77G  22% /mnt/smb
...
```

In this example, there is a **/mnt/smb** directory mounted as a Common Internet File System (CIFS) filesystem.

5.20.7. Additional resources

- Configuring CSI volumes

5.21. VMWARE VSPHERE CSI DRIVER OPERATOR

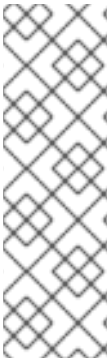
5.21.1. Overview

OpenShift Container Platform can provision persistent volumes (PVs) using the Container Storage Interface (CSI) VMware vSphere driver for Virtual Machine Disk (VMDK) volumes.

Familiarity with persistent storage and configuring CSI volumes is recommended when working with a CSI Operator and driver.

To create CSI-provisioned persistent volumes (PVs) that mount to vSphere storage assets, OpenShift Container Platform installs the vSphere CSI Driver Operator and the vSphere CSI driver by default in the **openshift-cluster-csi-drivers** namespace.

- **vSphere CSI Driver Operator**: The Operator provides a storage class, called **thin-csi**, that you can use to create persistent volumes claims (PVCs). The vSphere CSI Driver Operator supports dynamic volume provisioning by allowing storage volumes to be created on-demand, eliminating the need for cluster administrators to pre-provision storage. You can disable this default storage class if desired (see Managing the default storage class).
- **vSphere CSI driver**: The driver enables you to create and mount vSphere PVs. In OpenShift Container Platform 4.18, the driver version is 3.3.1 The vSphere CSI driver supports all of the file systems supported by the underlying Red Hat Core operating system release, including XFS and Ext4. For more information about supported file systems, see Overview of available file systems.



NOTE

For new installations, OpenShift Container Platform 4.13 and later provides automatic migration for the vSphere in-tree volume plugin to its equivalent CSI driver. Updating to OpenShift Container Platform 4.15 and later also provides automatic migration. For more information about updating and migration, see CSI automatic migration.

CSI automatic migration should be seamless. Migration does not change how you use all existing API objects, such as persistent volumes, persistent volume claims, and storage classes.

5.21.2. About CSI

Storage vendors have traditionally provided storage drivers as part of Kubernetes. With the implementation of the Container Storage Interface (CSI), third-party providers can instead deliver storage plugins using a standard interface without ever having to change the core Kubernetes code.

CSI Operators give OpenShift Container Platform users storage options, such as volume snapshots, that are not possible with in-tree volume plugins.

5.21.3. vSphere CSI limitations

The following limitations apply to the vSphere Container Storage Interface (CSI) Driver Operator:

- The vSphere CSI Driver supports dynamic and static provisioning. However, when using static provisioning in the PV specifications, do not use the key **storage.kubernetes.io/csiProvisionerIdentity** in **csi.volumeAttributes** because this key indicates dynamically provisioned PVs.
- Migrating persistent container volumes between datastores using the vSphere client interface is not supported with OpenShift Container Platform.

5.21.4. vSphere storage policy

The vSphere CSI Driver Operator storage class uses vSphere's storage policy. OpenShift Container Platform automatically creates a storage policy that targets datastore configured in cloud configuration:

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: thin-csi
provisioner: csi.vsphere.vmware.com
parameters:
  StoragePolicyName: "$openshift-storage-policy-xxxx"
volumeBindingMode: WaitForFirstConsumer
allowVolumeExpansion: false
reclaimPolicy: Delete
```

5.21.5. ReadWriteMany vSphere volume support

If the underlying vSphere environment supports the vSAN file service, then vSphere Container Storage Interface (CSI) Driver Operator installed by OpenShift Container Platform supports provisioning of ReadWriteMany (RWX) volumes. If vSAN file service is not configured, then ReadWriteOnce (RWO) is the only access mode available. If you do not have vSAN file service configured, and you request RWX, the volume fails to get created and an error is logged.

For more information about configuring the vSAN file service in your environment, see vSAN File Service.

You can request RWX volumes by making the following persistent volume claim (PVC):

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: myclaim
spec:
  resources:
    requests:
      storage: 1Gi
  accessModes:
    - ReadWriteMany
  storageClassName: thin-csi
```

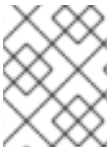
Requesting a PVC of the RWX volume type should result in provisioning of persistent volumes (PVs) backed by the vSAN file service.

5.21.6. VMware vSphere CSI Driver Operator requirements

To install the vSphere Container Storage Interface (CSI) Driver Operator, the following requirements must be met:

- VMware vSphere version: 7.0 Update 2 or later, or VMware Cloud Foundation 4.3 or later; 8.0 Update 1 or later, or VMware Cloud Foundation 5.0 or later
- vCenter version: 7.0 Update 2 or later, or VMware Cloud Foundation 4.3 or later; 8.0 Update 1 or later, or VMware Cloud Foundation 5.0 or later
- Virtual machines of hardware version 15 or later
- No third-party vSphere CSI driver already installed in the cluster

If a third-party vSphere CSI driver is present in the cluster, OpenShift Container Platform does not overwrite it. The presence of a third-party vSphere CSI driver prevents OpenShift Container Platform from updating to OpenShift Container Platform 4.13 or later.



NOTE

The VMware vSphere CSI Driver Operator is supported only on clusters deployed with **platform: vsphere** in the installation manifest.

You can create a custom role for the Container Storage Interface (CSI) driver, the vSphere CSI Driver Operator, and the vSphere Problem Detector Operator. The custom role can include privilege sets that assign a minimum set of permissions to each vSphere object. This means that the CSI driver, the vSphere CSI Driver Operator, and the vSphere Problem Detector Operator can establish a basic interaction with these objects.

IMPORTANT

Installing an OpenShift Container Platform cluster in a vCenter is tested against a full list of privileges as described in the "Required vCenter account privileges" section. By adhering to the full list of privileges, you can reduce the possibility of unexpected and unsupported behaviors that might occur when creating a custom role with a set of restricted privileges.

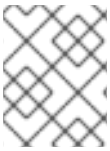
To remove a third-party CSI driver, see Removing a third-party vSphere CSI Driver .

5.21.7. Removing a third-party vSphere CSI Driver Operator

OpenShift Container Platform 4.10, and later, includes a built-in version of the vSphere Container Storage Interface (CSI) Operator Driver that is supported by Red Hat. If you have installed a vSphere CSI driver provided by the community or another vendor, updates to the next major version of OpenShift Container Platform, such as 4.13, or later, might be disabled for your cluster.

OpenShift Container Platform 4.12, and later, clusters are still fully supported, and updates to z-stream releases of 4.12, such as 4.12.z, are not blocked, but you must correct this state by removing the third-party vSphere CSI Driver before updates to next major version of OpenShift Container Platform can

occur. Removing the third-party vSphere CSI driver does not require deletion of associated persistent volume (PV) objects, and no data loss should occur.



NOTE

These instructions may not be complete, so consult the vendor or community provider uninstall guide to ensure removal of the driver and components.

To uninstall the third-party vSphere CSI Driver:

1. Delete the third-party vSphere CSI Driver (VMware vSphere Container Storage Plugin) Deployment and Daemonset objects.
2. Delete the configmap and secret objects that were installed previously with the third-party vSphere CSI Driver.
3. Delete the third-party vSphere CSI driver **CSIDriver** object:

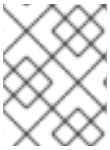
```
~ $ oc delete CSIDriver csi.vsphere.vmware.com
```

```
csidriver.storage.k8s.io "csi.vsphere.vmware.com" deleted
```

After you have removed the third-party vSphere CSI Driver from the OpenShift Container Platform cluster, installation of Red Hat's vSphere CSI Driver Operator automatically resumes, and any conditions that could block upgrades to OpenShift Container Platform 4.11, or later, are automatically removed. If you had existing vSphere CSI PV objects, their lifecycle is now managed by Red Hat's vSphere CSI Driver Operator.

5.21.8. vSphere persistent disks encryption

You can encrypt virtual machines (VMs) and dynamically provisioned persistent volumes (PVs) on OpenShift Container Platform running on top of vSphere.



NOTE

OpenShift Container Platform does not support RWX-encrypted PVs. You cannot request RWX PVs out of a storage class that uses an encrypted storage policy.

You must encrypt VMs before you can encrypt PVs, which you can do during or after installation.

For information about encrypting VMs, see:

- Requirements for encrypting virtual machines
- During installation: Step 7 of Installing RHCOS and starting the OpenShift Container Platform bootstrap process
- Enabling encryption on a vSphere cluster

After encrypting VMs, you can configure a storage class that supports dynamic encryption volume provisioning using the vSphere Container Storage Interface (CSI) driver. This can be accomplished in one of two ways using:

- Datastore URL: This approach is not very flexible, and forces you to use a single datastore. It also does not support topology-aware provisioning.
- Tag-based placement: Encrypts the provisioned volumes and uses tag-based placement to target specific datastores.

5.21.8.1. Using datastore URL

Procedure

To encrypt using the datastore URL:

1. Find out the name of the default storage policy in your datastore that supports encryption. This is same policy that was used for encrypting your VMs.
2. Create a storage class that uses this storage policy:

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
 name: encryption
provisioner: csi.vsphere.vmware.com
parameters:
 storagePolicyName: <storage-policy-name> 1
 datastoreurl: "ds:///vmfs/volumes/vsan:522e875627d-b090c96b526bb79c/"
```

1 Name of default storage policy in your datastore that supports encryption

5.21.8.2. Using tag-based placement

Procedure

To encrypt using tag-based placement:

1. In vCenter create a category for tagging datastores that will be made available to this storage class. Also, ensure that **StoragePod(Datastore clusters)**, **Datastore**, and **Folder** are selected as Associable Entities for the created category.
2. In vCenter, create a tag that uses the category created earlier.
3. Assign the previously created tag to each datastore that will be made available to the storage class. Make sure that datastores are shared with hosts participating in the OpenShift Container Platform cluster.
4. In vCenter, from the main menu, click **Policies and Profiles**.
5. On the **Policies and Profiles** page, in the navigation pane, click **VM Storage Policies**.
6. Click **CREATE**.
7. Type a name for the storage policy.
8. Select **Enable host based rules** and **Enable tag based placement rules**
9. In the **Next** tab:

a. Select **Encryption** and **Default Encryption Properties**.

b. Select the tag category created earlier, and select tag selected. Verify that the policy is selecting matching datastores.

10. Create the storage policy.

11. Create a storage class that uses the storage policy:

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
 name:  csi-encrypted
provisioner: csi.vsphere.vmware.com
reclaimPolicy: Delete
volumeBindingMode: WaitForFirstConsumer
parameters:
 storagePolicyName: <storage-policy-name> 1
```

1 Name of the storage policy that you created for encryption

5.21.9. Multiple vCenter support for vSphere CSI

Deploying OpenShift Container Platform across multiple vSphere vCenter clusters without shared storage for high availability can be helpful. OpenShift Container Platform v4.17, and later, supports this capability.

NOTE

Multiple vCenters can only be configured **during** installation. Multiple vCenters **cannot** be configured after installation.

The maximum number of supported vCenter clusters is three.

5.21.9.1. Configuring multiple vCenters during installation

To configure multiple vCenters during installation:

- Specify multiple vSphere clusters during installation. For information, see "Installation configuration parameters for vSphere".

Additional resources

- Installation configuration parameters for vSphere.

5.21.10. vSphere CSI topology overview

OpenShift Container Platform provides the ability to deploy OpenShift Container Platform for vSphere on different zones and regions, which allows you to deploy over multiple compute clusters and data centers, thus helping to avoid a single point of failure.

This is accomplished by defining zone and region categories in vCenter, and then assigning these categories to different failure domains, such as a compute cluster, by creating tags for these zone and

region categories. After you have created the appropriate categories, and assigned tags to vCenter objects, you can create additional machinesets that create virtual machines (VMs) that are responsible for scheduling pods in those failure domains.

The following example defines two failure domains with one region and two zones:

Table 5.6. vSphere storage topology with one region and two zones

Compute cluster	Failure domain	Description
Compute cluster: ocp1, Data center: Atlanta	openshift-region: us-east-1 (tag), openshift-zone: us-east-1a (tag)	This defines a failure domain in region us-east-1 with zone us-east-1a.
Computer cluster: ocp2, Data center: Atlanta	openshift-region: us-east-1 (tag), openshift-zone: us-east-1b (tag)	This defines a different failure domain within the same region called us-east-1b.

5.21.10.1. vSphere CSI topology requirements

The following guidelines are recommended for vSphere CSI topology:

- You are strongly recommended to add topology tags to data centers and compute clusters, and **not** to hosts.
  vsphere-problem-detector provides alerts if the **openshift-region** or **openshift-zone** tags are not defined at the data center or compute cluster level, and each topology tag (**openshift-region** or **openshift-zone**) should occur only once in the hierarchy.

  NOTE

  Ignoring this recommendation only results in a log warning from the CSI driver and duplicate tags lower in the hierarchy, such as hosts, are ignored; VMware considers this an invalid configuration, and therefore to prevent problems you should not use it.

- Volume provisioning requests in topology-aware environments attempt to create volumes in datastores accessible to all hosts under a given topology segment. This includes hosts that do not have Kubernetes node VMs running on them. For example, if the vSphere Container Storage Plug-in driver receives a request to provision a volume in **zone-a**, applied on the data center **dc-1**, all hosts under **dc-1** must have access to the datastore selected for volume provisioning. The hosts include those that are directly under **dc-1**, and those that are a part of clusters inside **dc-1**.

- For additional recommendations, you should read the VMware Guidelines and Best Practices for Deployment with Topology section.

5.21.10.2. Creating vSphere storage topology during installation

5.21.10.2.1. Procedure

- Specify the topology during installation. See the *Configuring regions and zones for a VMware vCenter* section.

No additional action is necessary and the default storage class that is created by OpenShift Container Platform is topology aware and should allow provisioning of volumes in different failure domains.

Additional resources

- Configuring regions and zones for a VMware vCenter

5.21.10.3. Creating vSphere storage topology postinstallation

5.21.10.3.1. Procedure

1. In the VMware vCenter vSphere client GUI, define appropriate zone and region catagories and tags.
   While vSphere allows you to create categories with any arbitrary name, OpenShift Container Platform strongly recommends use of **openshift-region** and **openshift-zone** names for defining topology categories.

   For more information about vSphere categories and tags, see the VMware vSphere documentation.

2. In OpenShift Container Platform, create failure domains. See the *Specifying multiple regions and zones for your cluster on vSphere* section.

3. Create a tag to assign to datastores across failure domains:
   When an OpenShift Container Platform spans more than one failure domain, the datastore might not be shared across those failure domains, which is where topology-aware provisioning of persistent volumes (PVs) is useful.

   a. In vCenter, create a category for tagging the datastores. For example, **openshift-zonal-datastore-cat**. You can use any other category name, provided the category uniquely is used for tagging datastores participating in OpenShift Container Platform cluster. Also, ensure that **StoragePod**, **Datastore**, and **Folder** are selected as Associable Entities for the created category.

   b. In vCenter, create a tag that uses the previously created category. This example uses the tag name **openshift-zonal-datastore**.

   c. Assign the previously created tag (in this example **openshift-zonal-datastore**) to each datastore in a failure domain that would be considered for dynamic provisioning.

   NOTE

   You can use any names you like for datastore categories and tags. The names used in this example are provided as recommendations. Ensure that the tags and categories that you define uniquely identify only datastores that are shared with all hosts in the OpenShift Container Platform cluster.

4. As needed, create a storage policy that targets the tag-based datastores in each failure domain:

   a. In vCenter, from the main menu, click **Policies and Profiles**.

   b. On the **Policies and Profiles** page, in the navigation pane, click **VM Storage Policies**.

   c. Click **CREATE**.

d. Type a name for the storage policy.

e. For the rules, choose Tag Placement rules and select the tag and category that targets the desired datastores (in this example, the **openshift-zonal-datastore** tag).
The datastores are listed in the storage compatibility table.

5. Create a new storage class that uses the new zoned storage policy:

a. Click **Storage** > **StorageClasses**.

b. On the **StorageClasses** page, click **Create StorageClass**.

c. Type a name for the new storage class in **Name**.

d. Under **Provisioner**, select **csi.vsphere.vmware.com**.

e. Under **Additional parameters**, for the StoragePolicyName parameter, set **Value** to the name of the new zoned storage policy that you created earlier.

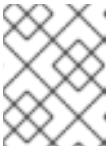
f. Click **Create**.

Example output

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: zoned-sc (1)
provisioner: csi.vsphere.vmware.com
parameters:
  StoragePolicyName: zoned-storage-policy (2)
reclaimPolicy: Delete
allowVolumeExpansion: true
volumeBindingMode: WaitForFirstConsumer
```

(1) New topology aware storage class name.

(2) Specify zoned storage policy.



NOTE

You can also create the storage class by editing the preceding YAML file and running the command **oc create -f $FILE**.

Additional resources

- Specifying multiple regions and zones for your cluster on vSphere
- VMware vSphere tag documentation

5.21.10.4. Creating vSphere storage topology without an infra topology

NOTE

OpenShift Container Platform recommends using the infrastructure object for specifying failure domains in a topology aware setup. Specifying failure domains in the infrastructure object and specify topology-categories in the **ClusterCSIDriver** object at the same time is an unsupported operation.

5.21.10.4.1. Procedure

1. In the VMware vCenter vSphere client GUI, define appropriate zone and region catagories and tags.
   While vSphere allows you to create categories with any arbitrary name, OpenShift Container Platform strongly recommends use of **openshift-region** and **openshift-zone** names for defining topology.

   For more information about vSphere categories and tags, see the VMware vSphere documentation.

2. To allow the container storage interface (CSI) driver to detect this topology, edit the **clusterCSIDriver** object YAML file **driverConfig** section:

   - Specify the **openshift-zone** and **openshift-region** categories that you created earlier.
   - Set **driverType** to **vSphere**.

   ```
   ~ $ oc edit clustercsidriver csi.vsphere.vmware.com -o yaml
   ```

   Example output

   ```
   apiVersion: operator.openshift.io/v1
   kind: ClusterCSIDriver
   metadata:
     name: csi.vsphere.vmware.com
   spec:
     logLevel: Normal
     managementState: Managed
     observedConfig: null
     operatorLogLevel: Normal
     unsupportedConfigOverrides: null
     driverConfig:
       driverType: vSphere (1)
         vSphere:
           topologyCategories: (2)
           - openshift-zone
           - openshift-region
   ```

   (1) Ensure that **driverType** is set to **vSphere**.

   (2) **openshift-zone** and **openshift-region** categories created earlier in vCenter.

3. Verify that **CSINode** object has topology keys by running the following commands:

   ```
   ~ $ oc get csinode
   ```

Example output

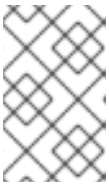
```
NAME DRIVERS AGE
co8-4s88d-infra-2m5vd 1 27m
co8-4s88d-master-0 1 70m
co8-4s88d-master-1 1 70m
co8-4s88d-master-2 1 70m
co8-4s88d-worker-j2hmg 1 47m
co8-4s88d-worker-mbb46 1 47m
co8-4s88d-worker-zlk7d 1 47m
```

```
~ $ oc get csinode co8-4s88d-worker-j2hmg -o yaml
```

Example output

```
...
spec:
  drivers:
  - allocatable:
      count: 59
  name: csi-vsphere.vmware.com
  nodeID: co8-4s88d-worker-j2hmg
  topologyKeys: 1
  - topology.csi.vmware.com/openshift-zone
  - topology.csi.vmware.com/openshift-region
```

1 Topology keys from vSphere **openshift-zone** and **openshift-region** catagories.



NOTE

CSINode objects might take some time to receive updated topology information. After the driver is updated, **CSINode** objects should have topology keys in them.

4. Create a tag to assign to datastores across failure domains:
When an OpenShift Container Platform spans more than one failure domain, the datastore might not be shared across those failure domains, which is where topology-aware provisioning of persistent volumes (PVs) is useful.

   a. In vCenter, create a category for tagging the datastores. For example, **openshift-zonal-datastore-cat**. You can use any other category name, provided the category uniquely is used for tagging datastores participating in OpenShift Container Platform cluster. Also, ensure that **StoragePod**, **Datastore**, and **Folder** are selected as Associable Entities for the created category.

   b. In vCenter, create a tag that uses the previously created category. This example uses the tag name **openshift-zonal-datastore**.

   c. Assign the previously created tag (in this example **openshift-zonal-datastore**) to each datastore in a failure domain that would be considered for dynamic provisioning.

NOTE

You can use any names you like for categories and tags. The names used in this example are provided as recommendations. Ensure that the tags and categories that you define uniquely identify only datastores that are shared with all hosts in the OpenShift Container Platform cluster.

5. Create a storage policy that targets the tag-based datastores in each failure domain:
   a. In vCenter, from the main menu, click **Policies and Profiles**.
   b. On the **Policies and Profiles** page, in the navigation pane, click **VM Storage Policies**.
   c. Click **CREATE**.
   d. Type a name for the storage policy.
   e. For the rules, choose Tag Placement rules and select the tag and category that targets the desired datastores (in this example, the **openshift-zonal-datastore** tag).
   The datastores are listed in the storage compatibility table.
6. Create a new storage class that uses the new zoned storage policy:
   a. Click **Storage** > **StorageClasses**.
   b. On the **StorageClasses** page, click **Create StorageClass**.
   c. Type a name for the new storage class in **Name**.
   d. Under **Provisioner**, select **csi.vsphere.vmware.com**.
   e. Under **Additional parameters**, for the StoragePolicyName parameter, set **Value** to the name of the new zoned storage policy that you created earlier.
   f. Click **Create**.

Example output

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: zoned-sc (1)
provisioner: csi.vsphere.vmware.com
parameters:
  StoragePolicyName: zoned-storage-policy (2)
reclaimPolicy: Delete
allowVolumeExpansion: true
volumeBindingMode: WaitForFirstConsumer
```

(1) New topology aware storage class name.

(2) Specify zoned storage policy.

NOTE

You can also create the storage class by editing the preceding YAML file and running the command **oc create -f $FILE**.

Additional resources

- VMware vSphere tag documentation

5.21.10.5. Results

Creating persistent volume claims (PVCs) and PVs from the topology aware storage class are truly zonal, and should use the datastore in their respective zone depending on how pods are scheduled:

```
~ $ oc get pv <pv-name> -o yaml
```

Example output

```
...
nodeAffinity:
  required:
    nodeSelectorTerms:
    - matchExpressions:
      - key: topology.csi.vmware.com/openshift-zone 1
        operator: In
        values:
        - <openshift-zone>
      -key: topology.csi.vmware.com/openshift-region 2
        operator: In
        values:
        - <openshift-region>
...
peristentVolumeclaimPolicy: Delete
storageClassName: <zoned-storage-class-name> 3
volumeMode: Filesystem
...
```

1 2 PV has zoned keys.

3 PV is using the zoned storage class.

5.21.11. Changing the maximum number of snapshots for vSphere

The default maximum number of snapshots per volume in vSphere Container Storage Interface (CSI) is 3. You can change the maximum number up to 32 per volume.

However, be aware that increasing the snapshot maximum involves a performance trade off, so for better performance use only 2 to 3 snapshots per volume.

For more VMware snapshot performance recommendations, see ***Additional resources***.

Prerequisites

- Access to the cluster with administrator rights.

Procedure

1. Check the current secret by the running the following command:

```
$ oc -n openshift-cluster-csi-drivers get secret/vsphere-csi-config-secret -o
jsonpath='{.data.cloud\.conf}' | base64 -d
```

Example output

```
# Labels with topology values are added dynamically via operator
[Global]
cluster-id = vsphere-01-cwv8p

# Populate VCenters (multi) after here
[VirtualCenter "vcenter.openshift.com"]
insecure-flag           = true
datacenters             = DEVQEdatacenter
password                = "xxxxxxxx"
user                  = "xxxxxxxx@devcluster.openshift.com"
migration-datastore-url = ds:///vmfs/volumes/vsan:52c842f232751e0d-3253aadeac21ca82/
```

In this example, the global maximum number of snapshots is not configured, so the default value of 3 is applied.

2. Change the snapshot limit by running the following command:

- Set **global** snapshot limit:

```
$ oc patch clustercsidriver/csi.vsphere.vmware.com --type=merge -p '{"spec":
{"driverConfig":{"vSphere":{"globalMaxSnapshotsPerBlockVolume": 10}}}}'

clustercsidriver.operator.openshift.io/csi.vsphere.vmware.com patched
```

In this example, the global limit is being changed to 10 (**globalMaxSnapshotsPerBlockVolume** set to 10).

- Set **Virtual Volume** snapshot limit:
This parameter sets the limit on the Virtual Volumes datastore only. The Virtual Volume maximum snapshot limit overrides the global constraint if set, but defaults to the global limit if it is not set.

```
$ oc patch clustercsidriver/csi.vsphere.vmware.com --type=merge -p '{"spec":
{"driverConfig":{"vSphere":{"granularMaxSnapshotsPerBlockVolumeInVVOL": 5}}}}'
clustercsidriver.operator.openshift.io/csi.vsphere.vmware.com patched
```

In this example, the Virtual Volume limit is being changed to 5 (**granularMaxSnapshotsPerBlockVolumeInVVOL** set to 5).

- Set **vSAN** snapshot limit:
This parameter sets the limit on the vSAN datastore only. The vSAN maximum snapshot limit overrides the global constraint if set, but defaults to the global limit if it is not set. You can set a maximum value of 32 under vSAN ESA setup.

```
$ oc patch clustercsidriver/csi.vsphere.vmware.com --type=merge -p '{"spec":
{"driverConfig":{"vSphere":{"granularMaxSnapshotsPerBlockVolumeInVSAN": 7}}}}'
clustercsidriver.operator.openshift.io/csi.vsphere.vmware.com patched
```

In this example, the vSAN limit is being changed to 7 (**granularMaxSnapshotsPerBlockVolumeInVSAN** set to 7).

Verification

- Verify that any changes you made are reflected in the config map by running the following command:

```
$ oc -n openshift-cluster-csi-drivers get secret/vsphere-csi-config-secret -o
jsonpath='{.data.cloud\.conf}' | base64 -d
```

Example output

```
# Labels with topology values are added dynamically via operator
[Global]
cluster-id = vsphere-01-cwv8p

# Populate VCenters (multi) after here
[VirtualCenter "vcenter.openshift.com"]
insecure-flag          = true
datacenters            = DEVQEdatacenter
password               = "xxxxxxxx"
user                 = "xxxxxxxx@devcluster.openshift.com"
migration-datastore-url = ds:///vmfs/volumes/vsan:52c842f232751e0d-3253aadeac21ca82/

[Snapshot]
global-max-snapshots-per-block-volume = 10 (1)
```

(1) **global-max-snapshots-per-block-volume** is now set to 10.

5.21.12. Disabling and enabling storage on vSphere

Cluster administrators might want to disable the VMware vSphere Container Storage Interface (CSI) Driver as a Day 2 operation, so the vSphere CSI Driver does not interface with your vSphere setup.

IMPORTANT

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

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

5.21.12.1. Consequences of disabling and enabling storage on vSphere

The consequences of disabling and enabling storage on vSphere are described in the following table.

Table 5.7. Consequences of disabling/enabling storage on vSphere

Disabling	Enabling

• vSphere CSI Driver Operator un-installs the CSI driver.
• Storage container orchestration (CO) should be healthy.
• vSphere-problem-detector continues running, but does not emit alerts or events, and checks less frequently (once per 24 hours).
• All existing persistent volumes (PVs), persistent volume claims (PVCs), and vSphere storage policies are unchanged:
  ◦ vSphere PVs cannot be used in new pods.
  ◦ vSphere PVs stay mounted and attached forever to existing nodes for existing pods. These pods remain in terminating state indefinitely after deletion.
• Storage classes are removed
	* vSphere CSI Driver Operator re-installs the CSI driver.
	
	* If necessary, the vSphere CSI Driver Operator creates the vSphere storage policy.

5.21.12.2. Disabling and enabling storage on vSphere

IMPORTANT

Before running this procedure, carefully review the preceding "Consequences of disabling and enabling storage on vSphere" table and potential impacts to your environment.

Procedure

To disable or enable storage on vSphere:

1. Click **Administration** > **CustomResourceDefinitions**.
2. On the **CustomResourceDefinitions** page next to the **Name** dropdown box, type "clustercsidriver".
3. Click **CRD ClusterCSIDriver**.
4. Click the **Instances** tab.
5. Click **csi.vsphere.vmware.com**.
6. Click the **YAML** tab.
7. For **spec.managementState**, change the value to **Removed** or **Managed**:

- **Removed**: storage is disabled
- **Managed**: storage is enabled

8. Click **Save**.
9. If you are disabling storage, confirm that the driver has been removed:
   a. Click **Workloads** > **Pods**.
   b. On the **Pods** page, in the **Name** filter box type "vmware-vsphere-csi-driver".
   The only item that should appear is the operator. For example: " vmware-vsphere-csi-driver-operator-559b97ffc5-w99fm"

5.21.13. Additional resources

- Configuring CSI volumes
- Best practices for using VMware snapshots in the vSphere environment

CHAPTER 6. GENERIC EPHEMERAL VOLUMES

6.1. OVERVIEW

Generic ephemeral volumes are a type of ephemeral volume that can be provided by all storage drivers that support persistent volumes and dynamic provisioning. Generic ephemeral volumes are similar to **emptyDir** volumes in that they provide a per-pod directory for scratch data, which is usually empty after provisioning.

Generic ephemeral volumes are specified inline in the pod spec and follow the pod's lifecycle. They are created and deleted along with the pod.

Generic ephemeral volumes have the following features:

- Storage can be local or network-attached.
- Volumes can have a fixed size that pods are not able to exceed.
- Volumes might have some initial data, depending on the driver and parameters.
- Typical operations on volumes are supported, assuming that the driver supports them, including snapshotting, cloning, resizing, and storage capacity tracking.

NOTE

Generic ephemeral volumes do not support offline snapshots and resize.

Due to this limitation, the following Container Storage Interface (CSI) drivers do not support the following features for generic ephemeral volumes:

- Azure Disk CSI driver does not support resize.
- Cinder CSI driver does not support snapshot.

6.2. LIFECYCLE AND PERSISTENT VOLUME CLAIMS

The parameters for a volume claim are allowed inside a volume source of a pod. Labels, annotations, and the whole set of fields for persistent volume claims (PVCs) are supported. When such a pod is created, the ephemeral volume controller then creates an actual PVC object (from the template shown in the *Creating generic ephemeral volumes* procedure) in the same namespace as the pod, and ensures that the PVC is deleted when the pod is deleted. This triggers volume binding and provisioning in one of two ways:

- Either immediately, if the storage class uses immediate volume binding.
  With immediate binding, the scheduler is forced to select a node that has access to the volume after it is available.
- When the pod is tentatively scheduled onto a node (**WaitForFirstConsumervolume** binding mode).
  This volume binding option is recommended for generic ephemeral volumes because then the scheduler can choose a suitable node for the pod.

In terms of resource ownership, a pod that has generic ephemeral storage is the owner of the PVCs that provide that ephemeral storage. When the pod is deleted, the Kubernetes garbage collector deletes the PVC, which then usually triggers deletion of the volume because the default reclaim policy of storage

classes is to delete volumes. You can create quasi-ephemeral local storage by using a storage class with a reclaim policy of retain: the storage outlives the pod, and in this case, you must ensure that volume clean-up happens separately. While these PVCs exist, they can be used like any other PVC. In particular, they can be referenced as data source in volume cloning or snapshotting. The PVC object also holds the current status of the volume.

Additional resources

- Creating generic ephemeral volumes

6.3. SECURITY

You can enable the generic ephemeral volume feature to allows users who can create pods to also create persistent volume claims (PVCs) indirectly. This feature works even if these users do not have permission to create PVCs directly. Cluster administrators must be aware of this. If this does not fit your security model, use an admission webhook that rejects objects such as pods that have a generic ephemeral volume.

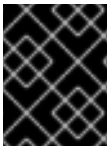
The normal namespace quota for PVCs still applies, so even if users are allowed to use this new mechanism, they cannot use it to circumvent other policies.

6.4. PERSISTENT VOLUME CLAIM NAMING

Automatically created persistent volume claims (PVCs) are named by a combination of the pod name and the volume name, with a hyphen (-) in the middle. This naming convention also introduces a potential conflict between different pods, and between pods and manually created PVCs.

For example, **pod-a** with volume **scratch** and **pod** with volume **a-scratch** both end up with the same PVC name, **pod-a-scratch**.

Such conflicts are detected, and a PVC is only used for an ephemeral volume if it was created for the pod. This check is based on the ownership relationship. An existing PVC is not overwritten or modified, but this does not resolve the conflict. Without the right PVC, a pod cannot start.



IMPORTANT

Be careful when naming pods and volumes inside the same namespace so that naming conflicts do not occur.

6.5. CREATING GENERIC EPHEMERAL VOLUMES

Procedure

1. Create the **pod** object definition and save it to a file.
2. Include the generic ephemeral volume information in the file.

my-example-pod-with-generic-vols.yaml

```
kind: Pod
apiVersion: v1
metadata:
  name: my-app
```

```
spec:
  containers:
    - name: my-frontend
      image: busybox:1.28
      volumeMounts:
      - mountPath: "/mnt/storage"
        name: data
      command: [ "sleep", "1000000" ]
  volumes:
    - name: data 1
      ephemeral:
        volumeClaimTemplate:
          metadata:
            labels:
              type: my-app-ephvol
          spec:
            accessModes: [ "ReadWriteOnce" ]
            storageClassName: "gp2-csi"
            resources:
              requests:
                storage: 1Gi
```

1 Generic ephemeral volume claim.

CHAPTER 7. EXPANDING PERSISTENT VOLUMES

7.1. ENABLING VOLUME EXPANSION SUPPORT

Before you can expand persistent volumes, the **StorageClass** object must have the **allowVolumeExpansion** field set to **true**.

Procedure

- Edit the **StorageClass** object and add the **allowVolumeExpansion** attribute by running the following command:

```
$ oc edit storageclass <storage_class_name> 1
```

1 Specifies the name of the storage class.

The following example demonstrates adding this line at the bottom of the storage class configuration.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
...
parameters:
  type: gp2
reclaimPolicy: Delete
allowVolumeExpansion: true 1
```

1 Setting this attribute to **true** allows PVCs to be expanded after creation.

7.2. EXPANDING CSI VOLUMES

You can use the Container Storage Interface (CSI) to expand storage volumes after they have already been created.

CSI volume expansion does not support the following:

- Recovering from failure when expanding volumes
- Shrinking

Prerequisites

- The underlying CSI driver supports resize.
- Dynamic provisioning is used.
- The controlling **StorageClass** object has **allowVolumeExpansion** set to **true**. For more information, see "Enabling volume expansion support."

Procedure

1. For the persistent volume claim (PVC), set **.spec.resources.requests.storage** to the desired new size.

2. Watch the **status.conditions** field of the PVC to see if the resize has completed. OpenShift Container Platform adds the **Resizing** condition to the PVC during expansion, which is removed after expansion completes.

7.3. EXPANDING FLEXVOLUME WITH A SUPPORTED DRIVER

When using FlexVolume to connect to your back-end storage system, you can expand persistent storage volumes after they have already been created. This is done by manually updating the persistent volume claim (PVC) in OpenShift Container Platform.

FlexVolume allows expansion if the driver is set with **RequiresFSResize** to **true**. The FlexVolume can be expanded on pod restart.

Similar to other volume types, FlexVolume volumes can also be expanded when in use by a pod.

Prerequisites

- The underlying volume driver supports resize.
- The driver is set with the **RequiresFSResize** capability to **true**.
- Dynamic provisioning is used.
- The controlling **StorageClass** object has **allowVolumeExpansion** set to **true**.

Procedure

- To use resizing in the FlexVolume plugin, you must implement the **ExpandableVolumePlugin** interface using these methods:

  RequiresFSResize

  If **true**, updates the capacity directly. If **false**, calls the **ExpandFS** method to finish the filesystem resize.

  ExpandFS

  If **true**, calls **ExpandFS** to resize filesystem after physical volume expansion is done. The volume driver can also perform physical volume resize together with filesystem resize.

IMPORTANT

Because OpenShift Container Platform does not support installation of FlexVolume plugins on control plane nodes, it does not support control-plane expansion of FlexVolume.

7.4. EXPANDING LOCAL VOLUMES

You can manually expand persistent volumes (PVs) and persistent volume claims (PVCs) created by using the local storage operator (LSO).

Procedure

1. Expand the underlying devices. Ensure that appropriate capacity is available on these devices.

2. Update the corresponding PV objects to match the new device sizes by editing the **.spec.capacity** field of the PV.

3. For the storage class that is used for binding the PVC to PVet, set **allowVolumeExpansion:true**.

4. For the PVC, set **.spec.resources.requests.storage** to match the new size.

Kubelet should automatically expand the underlying file system on the volume, if necessary, and update the status field of the PVC to reflect the new size.

7.5. EXPANDING PERSISTENT VOLUME CLAIMS (PVCS) WITH A FILE SYSTEM

Expanding PVCs based on volume types that need file system resizing, such as GCE, EBS, and Cinder, is a two-step process. First, expand the volume objects in the cloud provider. Second, expand the file system on the node.

Expanding the file system on the node only happens when a new pod is started with the volume.

Prerequisites

- The controlling **StorageClass** object must have **allowVolumeExpansion** set to **true**.

Procedure

1. Edit the PVC and request a new size by editing **spec.resources.requests**. For example, the following expands the **ebs** PVC to 8 Gi:

```
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: ebs
spec:
  storageClass: "storageClassWithFlagSet"
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 8Gi (1)
```

(1) Updating **spec.resources.requests** to a larger amount expands the PVC.

2. After the cloud provider object has finished resizing, the PVC is set to **FileSystemResizePending**. Check the condition by entering the following command:

```
$ oc describe pvc <pvc_name>
```

3. When the cloud provider object has finished resizing, the **PersistentVolume** object reflects the newly requested size in **PersistentVolume.Spec.Capacity**. At this point, you can create or recreate a new pod from the PVC to finish the file system resizing. Once the pod is running, the newly requested size is available and the **FileSystemResizePending** condition is removed from the PVC.

7.6. RECOVERING FROM FAILURE WHEN EXPANDING VOLUMES

If expanding underlying storage fails, the OpenShift Container Platform administrator can manually recover the persistent volume claim (PVC) state and cancel the resize requests. Otherwise, the resize requests are continuously retried by the controller.

Procedure

1. Mark the persistent volume (PV) that is bound to the PVC with the **Retain** reclaim policy. This can be done by editing the PV and changing **persistentVolumeReclaimPolicy** to **Retain**.
2. Delete the PVC.
3. Manually edit the PV and delete the **claimRef** entry from the PV specs to ensure that the newly created PVC can bind to the PV marked **Retain**. This marks the PV as **Available**.
4. Re-create the PVC in a smaller size, or a size that can be allocated by the underlying storage provider.
5. Set the **volumeName** field of the PVC to the name of the PV. This binds the PVC to the provisioned PV only.
6. Restore the reclaim policy on the PV.

Additional resources

- The controlling **StorageClass** object has **allowVolumeExpansion** set to **true** (see Enabling volume expansion support).

CHAPTER 8. DYNAMIC PROVISIONING

8.1. ABOUT DYNAMIC PROVISIONING

The **StorageClass** resource object describes and classifies storage that can be requested, as well as provides a means for passing parameters for dynamically provisioned storage on demand. **StorageClass** objects can also serve as a management mechanism for controlling different levels of storage and access to the storage. Cluster Administrators (**cluster-admin**) or Storage Administrators (**storage-admin**) define and create the **StorageClass** objects that users can request without needing any detailed knowledge about the underlying storage volume sources.

The OpenShift Container Platform persistent volume framework enables this functionality and allows administrators to provision a cluster with persistent storage. The framework also gives users a way to request those resources without having any knowledge of the underlying infrastructure.

Many storage types are available for use as persistent volumes in OpenShift Container Platform. While all of them can be statically provisioned by an administrator, some types of storage are created dynamically using the built-in provider and plugin APIs.

8.2. AVAILABLE DYNAMIC PROVISIONING PLUGINS

OpenShift Container Platform provides the following provisioner plugins, which have generic implementations for dynamic provisioning that use the cluster's configured provider's API to create new storage resources:

Storage type	Provisioner plugin name	Notes
Red Hat OpenStack Platform (RHOSP) Cinder	**kubernetes.io/cinder**	
RHOSP Manila Container Storage Interface (CSI)	**manila.csi.openstack.org**	Once installed, the OpenStack Manila CSI Driver Operator and ManilaDriver automatically create the required storage classes for all available Manila share types needed for dynamic provisioning.
Amazon Elastic Block Store (Amazon EBS)	**kubernetes.io/aws-ebs**	For dynamic provisioning when using multiple clusters in different zones, tag each node with **Key=kubernetes.io/cluster/<cluster_name>,Value=<cluster_id>** where **<cluster_name>** and **<cluster_id>** are unique per cluster.
Azure Disk	**kubernetes.io/azure-disk**	

Storage type	Provisioner plugin name	Notes
Azure File	**kubernetes.io/azure-file**	The **persistent-volume-binder** service account requires permissions to create and get secrets to store the Azure storage account and keys.
GCE Persistent Disk (gcePD)	**kubernetes.io/gce-pd**	In multi-zone configurations, it is advisable to run one OpenShift Container Platform cluster per GCE project to avoid PVs from being created in zones where no node in the current cluster exists.
IBM Power® Virtual Server Block	**powervs.csi.ibm.com**	After installation, the IBM Power® Virtual Server Block CSI Driver Operator and IBM Power® Virtual Server Block CSI Driver automatically create the required storage classes for dynamic provisioning.
VMware vSphere	**kubernetes.io/vsphere-volume**	

IMPORTANT

Any chosen provisioner plugin also requires configuration for the relevant cloud, host, or third-party provider as per the relevant documentation.

8.3. DEFINING A STORAGE CLASS

StorageClass objects are currently a globally scoped object and must be created by **cluster-admin** or **storage-admin** users.

IMPORTANT

The Cluster Storage Operator might install a default storage class depending on the platform in use. This storage class is owned and controlled by the Operator. It cannot be deleted or modified beyond defining annotations and labels. If different behavior is desired, you must define a custom storage class.

The following sections describe the basic definition for a **StorageClass** object and specific examples for each of the supported plugin types.

8.3.1. Basic StorageClass object definition

The following resource shows the parameters and default values that you use to configure a storage class. This example uses the AWS ElasticBlockStore (EBS) object definition.

Sample StorageClass definition

```
kind: StorageClass 1
apiVersion: storage.k8s.io/v1 2
metadata:
  name: <storage-class-name> 3
  annotations: 4
    storageclass.kubernetes.io/is-default-class: 'true'
    ...
provisioner: kubernetes.io/aws-ebs 5
parameters: 6
  type: gp3
...
```

1. (required) The API object type.
2. (required) The current apiVersion.
3. (required) The name of the storage class.
4. (optional) Annotations for the storage class.
5. (required) The type of provisioner associated with this storage class.
6. (optional) The parameters required for the specific provisioner, this will change from plug-in to plug-in.

8.3.2. Storage class annotations

To set a storage class as the cluster-wide default, add the following annotation to your storage class metadata:

```
storageclass.kubernetes.io/is-default-class: "true"
```

For example:

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  annotations:
    storageclass.kubernetes.io/is-default-class: "true"
...
```

This enables any persistent volume claim (PVC) that does not specify a specific storage class to automatically be provisioned through the default storage class. However, your cluster can have more than one storage class, but only one of them can be the default storage class.

NOTE

The beta annotation **storageclass.beta.kubernetes.io/is-default-class** is still working; however, it will be removed in a future release.

To set a storage class description, add the following annotation to your storage class metadata:

```
kubernetes.io/description: My Storage Class Description
```

For example:

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  annotations:
    kubernetes.io/description: My Storage Class Description
...
```

8.3.3. RHOSP Cinder object definition

cinder-storageclass.yaml

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: <storage-class-name> 1
provisioner: kubernetes.io/cinder
parameters:
  type: fast 2
  availability: nova 3
  fsType: ext4 4
```

1. Name of the storage class. The persistent volume claim uses this storage class for provisioning the associated persistent volumes.
2. Volume type created in Cinder. Default is empty.
3. Availability Zone. If not specified, volumes are generally round-robined across all active zones where the OpenShift Container Platform cluster has a node.
4. File system that is created on dynamically provisioned volumes. This value is copied to the **fsType** field of dynamically provisioned persistent volumes and the file system is created when the volume is mounted for the first time. The default value is **ext4**.

8.3.4. RHOSP Manila Container Storage Interface (CSI) object definition

Once installed, the OpenStack Manila CSI Driver Operator and ManilaDriver automatically create the required storage classes for all available Manila share types needed for dynamic provisioning.

8.3.5. AWS Elastic Block Store (EBS) object definition

aws-ebs-storageclass.yaml

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
```

```
  name: <storage-class-name> (1)
provisioner: kubernetes.io/aws-ebs
parameters:
  type: io1 (2)
  iopsPerGB: "10" (3)
  encrypted: "true" (4)
  kmsKeyId: keyvalue (5)
  fsType: ext4 (6)
```

(1) (required) Name of the storage class. The persistent volume claim uses this storage class for provisioning the associated persistent volumes.

(2) (required) Select from **io1**, **gp3**, **sc1**, **st1**. The default is **gp3**. See the AWS documentation for valid Amazon Resource Name (ARN) values.

(3) Optional: Only for **io1** volumes. I/O operations per second per GiB. The AWS volume plugin multiplies this with the size of the requested volume to compute IOPS of the volume. The value cap is 20,000 IOPS, which is the maximum supported by AWS. See the AWS documentation for further details.

(4) Optional: Denotes whether to encrypt the EBS volume. Valid values are **true** or **false**.

(5) Optional: The full ARN of the key to use when encrypting the volume. If none is supplied, but **encypted** is set to **true**, then AWS generates a key. See the AWS documentation for a valid ARN value.

(6) Optional: File system that is created on dynamically provisioned volumes. This value is copied to the **fsType** field of dynamically provisioned persistent volumes and the file system is created when the volume is mounted for the first time. The default value is **ext4**.

8.3.6. Azure Disk object definition

azure-advanced-disk-storageclass.yaml

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <storage-class-name> (1)
provisioner: kubernetes.io/azure-disk
volumeBindingMode: WaitForFirstConsumer (2)
allowVolumeExpansion: true
parameters:
  kind: Managed (3)
  storageaccounttype: Premium_LRS (4)
reclaimPolicy: Delete
```

(1) Name of the storage class. The persistent volume claim uses this storage class for provisioning the associated persistent volumes.

(2) Using **WaitForFirstConsumer** is strongly recommended. This provisions the volume while allowing enough storage to schedule the pod on a free worker node from an available zone.

(3) Possible values are **Shared** (default), **Managed**, and **Dedicated**.

IMPORTANT

Red Hat only supports the use of **kind: Managed** in the storage class.

With **Shared** and **Dedicated**, Azure creates unmanaged disks, while OpenShift Container Platform creates a managed disk for machine OS (root) disks. But because Azure Disk does not allow the use of both managed and unmanaged disks on a node, unmanaged disks created with **Shared** or **Dedicated** cannot be attached to OpenShift Container Platform nodes.

4 Azure storage account SKU tier. Default is empty. Note that Premium VMs can attach both **Standard_LRS** and **Premium_LRS** disks, Standard VMs can only attach **Standard_LRS** disks, Managed VMs can only attach managed disks, and unmanaged VMs can only attach unmanaged disks.

a. If **kind** is set to **Shared**, Azure creates all unmanaged disks in a few shared storage accounts in the same resource group as the cluster.

b. If **kind** is set to **Managed**, Azure creates new managed disks.

c. If **kind** is set to **Dedicated** and a **storageAccount** is specified, Azure uses the specified storage account for the new unmanaged disk in the same resource group as the cluster. For this to work:

- The specified storage account must be in the same region.
- Azure Cloud Provider must have write access to the storage account.

d. If **kind** is set to **Dedicated** and a **storageAccount** is not specified, Azure creates a new dedicated storage account for the new unmanaged disk in the same resource group as the cluster.

8.3.7. Azure File object definition

The Azure File storage class uses secrets to store the Azure storage account name and the storage account key that are required to create an Azure Files share. These permissions are created as part of the following procedure.

Procedure

1. Define a **ClusterRole** object that allows access to create and view secrets:

```
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRole
metadata:
#  name: system:azure-cloud-provider
  name: <persistent-volume-binder-role> 1
rules:
- apiGroups: ['']
  resources: ['secrets']
  verbs:     ['get','create']
```

1 The name of the cluster role to view and create secrets.

2. Add the cluster role to the service account:

```
$ oc adm policy add-cluster-role-to-user <persistent-volume-binder-role>
system:serviceaccount:kube-system:persistent-volume-binder
```

3. Create the Azure File **StorageClass** object:

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: <azure-file> (1)
provisioner: kubernetes.io/azure-file
parameters:
  location: eastus (2)
  skuName: Standard_LRS (3)
  storageAccount: <storage-account> (4)
reclaimPolicy: Delete
volumeBindingMode: Immediate
```

(1) Name of the storage class. The persistent volume claim uses this storage class for provisioning the associated persistent volumes.

(2) Location of the Azure storage account, such as **eastus**. Default is empty, meaning that a new Azure storage account will be created in the OpenShift Container Platform cluster's location.

(3) SKU tier of the Azure storage account, such as **Standard_LRS**. Default is empty, meaning that a new Azure storage account will be created with the **Standard_LRS** SKU.

(4) Name of the Azure storage account. If a storage account is provided, then **skuName** and **location** are ignored. If no storage account is provided, then the storage class searches for any storage account that is associated with the resource group for any accounts that match the defined **skuName** and **location**.

8.3.7.1. Considerations when using Azure File

The following file system features are not supported by the default Azure File storage class:

- Symlinks
- Hard links
- Extended attributes
- Sparse files
- Named pipes

Additionally, the owner user identifier (UID) of the Azure File mounted directory is different from the process UID of the container. The **uid** mount option can be specified in the **StorageClass** object to define a specific user identifier to use for the mounted directory.

The following **StorageClass** object demonstrates modifying the user and group identifier, along with enabling symlinks for the mounted directory.

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: azure-file
mountOptions:
  - uid=1500 1
  - gid=1500 2
  - mfsymlinks 3
provisioner: kubernetes.io/azure-file
parameters:
  location: eastus
  skuName: Standard_LRS
reclaimPolicy: Delete
volumeBindingMode: Immediate
```

1. Specifies the user identifier to use for the mounted directory.
2. Specifies the group identifier to use for the mounted directory.
3. Enables symlinks.

8.3.8. GCE PersistentDisk (gcePD) object definition

gce-pd-storageclass.yaml

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: <storage-class-name> 1
provisioner: kubernetes.io/gce-pd
parameters:
  type: pd-ssd 2
  replication-type: none
volumeBindingMode: WaitForFirstConsumer
allowVolumeExpansion: true
reclaimPolicy: Delete
```

1. Name of the storage class. The persistent volume claim uses this storage class for provisioning the associated persistent volumes.
2. Select **pd-ssd**, **pd-standard**, or **hyperdisk-balanced**. The default is **pd-ssd**.

8.3.9. VMware vSphere object definition

vsphere-storageclass.yaml

```
kind: StorageClass
apiVersion: storage.k8s.io/v1
metadata:
  name: <storage-class-name> 1
provisioner: csi.vsphere.vmware.com 2
```

1. Name of the storage class. The persistent volume claim uses this storage class for provisioning the associated persistent volumes.

2. For more information about using VMware vSphere CSI with OpenShift Container Platform, see the Kubernetes documentation.

8.4. CHANGING THE DEFAULT STORAGE CLASS

Use the following procedure to change the default storage class.

For example, if you have two defined storage classes, **gp3** and **standard**, and you want to change the default storage class from **gp3** to **standard**.

Prerequisites

- Access to the cluster with cluster-admin privileges.

Procedure

To change the default storage class:

1. List the storage classes:

```
$ oc get storageclass
```

Example output

```
NAME            TYPE
gp3 (default)    kubernetes.io/aws-ebs 1
standard        kubernetes.io/aws-ebs
```

1. **(default)** indicates the default storage class.

2. Make the desired storage class the default.
For the desired storage class, set the **storageclass.kubernetes.io/is-default-class** annotation to **true** by running the following command:

```
$ oc patch storageclass standard -p '{"metadata": {"annotations":
{"storageclass.kubernetes.io/is-default-class": "true"}}}'
```

NOTE

You can have multiple default storage classes for a short time. However, you should ensure that only one default storage class exists eventually.

With multiple default storage classes present, any persistent volume claim (PVC) requesting the default storage class (**pvc.spec.storageClassName**=nil) gets the most recently created default storage class, regardless of the default status of that storage class, and the administrator receives an alert in the alerts dashboard that there are multiple default storage classes, **MultipleDefaultStorageClasses**.

3. Remove the default storage class setting from the old default storage class.

For the old default storage class, change the value of the **storageclass.kubernetes.io/is-default-class** annotation to **false** by running the following command:

```
$ oc patch storageclass gp3 -p '{"metadata": {"annotations": {"storageclass.kubernetes.io/is-default-class": "false"}}}'
```

4. Verify the changes:

```
$ oc get storageclass
```

Example output

```
NAME                TYPE
gp3                 kubernetes.io/aws-ebs
standard (default)  kubernetes.io/aws-ebs
```

CHAPTER 9. DETACH VOLUMES AFTER NON-GRACEFUL NODE SHUTDOWN

This feature allows drivers to automatically detach volumes when a node goes down non-gracefully.

9.1. OVERVIEW

A graceful node shutdown occurs when the kubelet's node shutdown manager detects the upcoming node shutdown action. Non-graceful shutdowns occur when the kubelet does not detect a node shutdown action, which can occur because of system or hardware failures. Also, the kubelet may not detect a node shutdown action when the shutdown command does not trigger the Inhibitor Locks mechanism used by the kubelet on Linux, or because of a user error, for example, if the shutdownGracePeriod and shutdownGracePeriodCriticalPods details are not configured correctly for that node.

With this feature, when a non-graceful node shutdown occurs, you can manually add an **out-of-service** taint on the node to allow volumes to automatically detach from the node.

9.2. ADDING AN OUT-OF-SERVICE TAINT MANUALLY FOR AUTOMATIC VOLUME DETACHMENT

Prerequisites

- Access to the cluster with cluster-admin privileges.

Procedure

To allow volumes to detach automatically from a node after a non-graceful node shutdown:

1. After a node is detected as unhealthy, shut down the worker node.
2. Ensure that the node is shutdown by running the following command and checking the status:

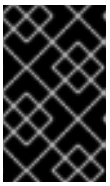
```
oc get node <node name> 1
```

1 <node name> = name of the non-gracefully shutdown node

IMPORTANT

If the node is not completely shut down, do not proceed with tainting the node. If the node is still up and the taint is applied, filesystem corruption can occur.

3. Taint the corresponding node object by running the following command:



IMPORTANT

Tainting a node this way deletes all pods on that node. This also causes any pods that are backed by statefulsets to be evicted, and replacement pods to be created on a different node.

```
oc adm taint node <node name> node.kubernetes.io/out-of-
service=nodeshutdown:NoExecute 1
```

1 <node name> = name of the non-gracefully shutdown node

After the taint is applied, the volumes detach from the shutdown node allowing their disks to be attached to a different node.

Example

The resulting YAML file resembles the following:

```
spec:
  taints:
  - effect: NoExecute
    key: node.kubernetes.io/out-of-service
    value: nodeshutdown
```

4. Restart the node.
5. Remove the taint from the corresponding node object by running the following command:

```
oc adm taint node <node name> node.kubernetes.io/out-of-
service=nodeshutdown:NoExecute- 1
```