



# OpenShift Container Platform 4.17

## Nodes

Configuring and managing nodes in OpenShift Container Platform



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## Abstract

This document provides instructions for configuring and managing the nodes, Pods, and containers in your cluster. It also provides information on configuring Pod scheduling and placement, using jobs and DaemonSets to automate tasks, and other tasks to ensure an efficient cluster.

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# CHAPTER 1. OVERVIEW OF NODES

## 1.1. ABOUT NODES

A node is a virtual or bare-metal machine in a Kubernetes cluster. Worker nodes host your application containers, grouped as pods. The control plane nodes run services that are required to control the Kubernetes cluster. In OpenShift Container Platform, the control plane nodes contain more than just the Kubernetes services for managing the OpenShift Container Platform cluster.

Having stable and healthy nodes in a cluster is fundamental to the smooth functioning of your hosted application. In OpenShift Container Platform, you can access, manage, and monitor a node through the **Node** object representing the node. Using the OpenShift CLI (**oc**) or the web console, you can perform the following operations on a node.

The following components of a node are responsible for maintaining the running of pods and providing the Kubernetes runtime environment.

### Container runtime

The container runtime is responsible for running containers. Kubernetes offers several runtimes such as containerd, cri-o, rktlet, and Docker.

### Kubelet

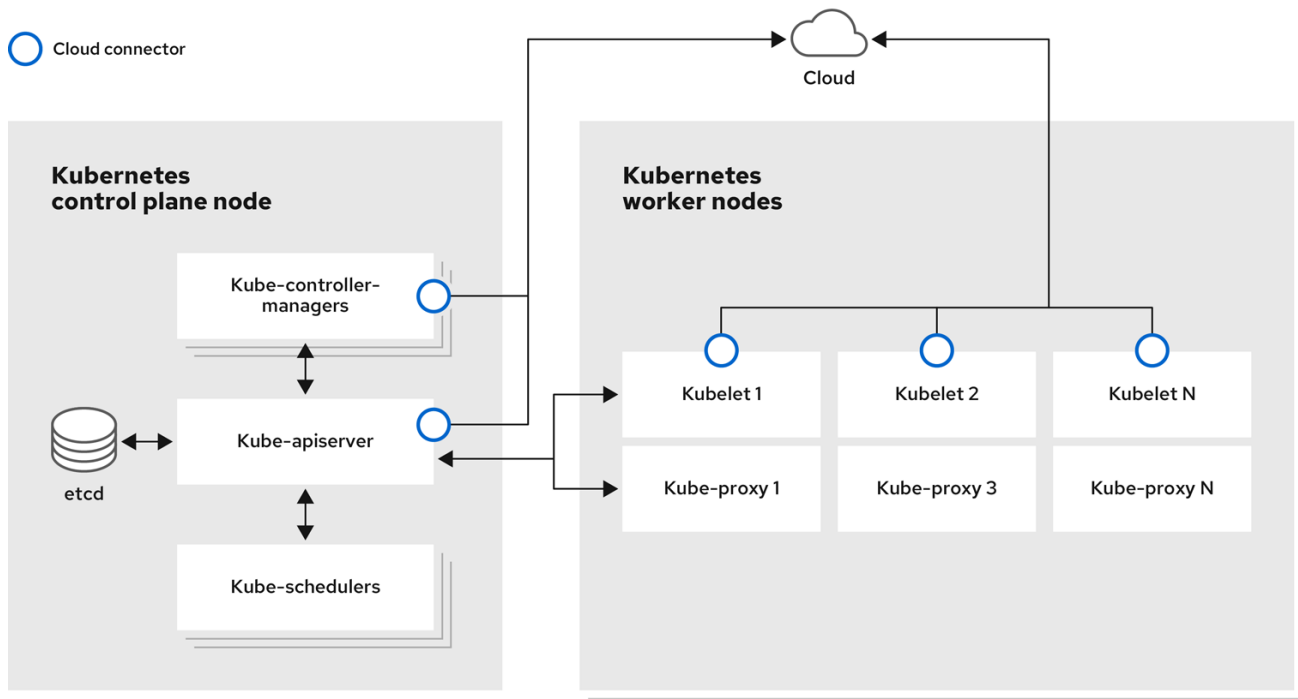
Kubelet runs on nodes and reads the container manifests. It ensures that the defined containers have started and are running. The kubelet process maintains the state of work and the node server. Kubelet manages network rules and port forwarding. The kubelet manages containers that are created by Kubernetes only.

### Kube-proxy

Kube-proxy runs on every node in the cluster and maintains the network traffic between the Kubernetes resources. A Kube-proxy ensures that the networking environment is isolated and accessible.

### DNS

Cluster DNS is a DNS server which serves DNS records for Kubernetes services. Containers started by Kubernetes automatically include this DNS server in their DNS searches.



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## Read operations

The read operations allow an administrator or a developer to get information about nodes in an OpenShift Container Platform cluster.

- [List all the nodes in a cluster](#) .
- Get information about a node, such as memory and CPU usage, health, status, and age.
- [List pods running on a node](#) .

## Management operations

As an administrator, you can easily manage a node in an OpenShift Container Platform cluster through several tasks:

- [Add or update node labels](#) . A label is a key-value pair applied to a **Node** object. You can control the scheduling of pods using labels.
- Change node configuration using a custom resource definition (CRD), or the **kubeletConfig** object.
- Configure nodes to allow or disallow the scheduling of pods. Healthy worker nodes with a **Ready** status allow pod placement by default while the control plane nodes do not; you can change this default behavior by [configuring the worker nodes to be unschedulable](#) and [the control plane nodes to be schedulable](#).
- [Allocate resources for nodes](#) using the **system-reserved** setting. You can allow OpenShift Container Platform to automatically determine the optimal **system-reserved** CPU and memory resources for your nodes, or you can manually determine and set the best resources for your nodes.
- [Configure the number of pods that can run on a node](#) based on the number of processor cores on the node, a hard limit, or both.

- Reboot a node gracefully using [pod anti-affinity](#).
- [Delete a node from a cluster](#) by scaling down the cluster using a compute machine set. To delete a node from a bare-metal cluster, you must first drain all pods on the node and then manually delete the node.

### Enhancement operations

OpenShift Container Platform allows you to do more than just access and manage nodes; as an administrator, you can perform the following tasks on nodes to make the cluster more efficient, application-friendly, and to provide a better environment for your developers.

- Manage node-level tuning for high-performance applications that require some level of kernel tuning by [using the Node Tuning Operator](#).
- Enable TLS security profiles on the node to protect communication between the kubelet and the Kubernetes API server.
- [Run background tasks on nodes automatically with daemon sets](#). You can create and use daemon sets to create shared storage, run a logging pod on every node, or deploy a monitoring agent on all nodes.
- [Free node resources using garbage collection](#). You can ensure that your nodes are running efficiently by removing terminated containers and the images not referenced by any running pods.
- [Add kernel arguments to a set of nodes](#).
- Configure an OpenShift Container Platform cluster to have worker nodes at the network edge (remote worker nodes). For information on the challenges of having remote worker nodes in an OpenShift Container Platform cluster and some recommended approaches for managing pods on a remote worker node, see [Using remote worker nodes at the network edge](#).

## 1.2. ABOUT PODS

A pod is one or more containers deployed together on a node. As a cluster administrator, you can define a pod, assign it to run on a healthy node that is ready for scheduling, and manage. A pod runs as long as the containers are running. You cannot change a pod once it is defined and is running. Some operations you can perform when working with pods are:

### Read operations

As an administrator, you can get information about pods in a project through the following tasks:

- [List pods associated with a project](#), including information such as the number of replicas and restarts, current status, and age.
- [View pod usage statistics](#) such as CPU, memory, and storage consumption.

### Management operations

The following list of tasks provides an overview of how an administrator can manage pods in an OpenShift Container Platform cluster.

- Control scheduling of pods using the advanced scheduling features available in OpenShift Container Platform:
  - Node-to-pod binding rules such as [pod affinity](#), [node affinity](#), and [anti-affinity](#).
  - [Node labels and selectors](#).

- [Taints and tolerations](#).
- [Pod topology spread constraints](#).
- [Secondary scheduling](#).
- [Configure the descheduler to evict pods](#) based on specific strategies so that the scheduler reschedules the pods to more appropriate nodes.
- [Configure how pods behave after a restart using pod controllers and restart policies](#) .
- [Limit both egress and ingress traffic on a pod](#) .
- [Add and remove volumes to and from any object that has a pod template](#) . A volume is a mounted file system available to all the containers in a pod. Container storage is ephemeral; you can use volumes to persist container data.

### Enhancement operations

You can work with pods more easily and efficiently with the help of various tools and features available in OpenShift Container Platform. The following operations involve using those tools and features to better manage pods.

Operation	User	More information
Create and use a horizontal pod autoscaler.	Developer	You can use a horizontal pod autoscaler to specify the minimum and the maximum number of pods you want to run, as well as the CPU utilization or memory utilization your pods should target. Using a horizontal pod autoscaler, you can <a href="#">automatically scale pods</a> .
<a href="#">Install and use a vertical pod autoscaler</a> .	Administrator and developer	As an administrator, use a vertical pod autoscaler to better use cluster resources by monitoring the resources and the resource requirements of workloads.  As a developer, use a vertical pod autoscaler to ensure your pods stay up during periods of high demand by scheduling pods to nodes that have enough resources for each pod.
Provide access to external resources using device plugins.	Administrator	A <a href="#">device plugin</a> is a gRPC service running on nodes (external to the kubelet), which manages specific hardware resources. You can <a href="#">deploy a device plugin</a> to provide a consistent and portable solution to consume hardware devices across clusters.

Operation	User	More information
Provide sensitive data to pods <a href="#">using the Secret object</a> .	Administrator	Some applications need sensitive information, such as passwords and usernames. You can use the <b>Secret</b> object to provide such information to an application pod.

## 1.3. ABOUT CONTAINERS

A container is the basic unit of an OpenShift Container Platform application, which comprises the application code packaged along with its dependencies, libraries, and binaries. Containers provide consistency across environments and multiple deployment targets: physical servers, virtual machines (VMs), and private or public cloud.

Linux container technologies are lightweight mechanisms for isolating running processes and limiting access to only designated resources. As an administrator, You can perform various tasks on a Linux container, such as:

- [Copy files to and from a container](#) .
- [Allow containers to consume API objects](#) .
- [Execute remote commands in a container](#) .
- [Use port forwarding to access applications in a container](#) .

OpenShift Container Platform provides specialized containers called [Init containers](#). Init containers run before application containers and can contain utilities or setup scripts not present in an application image. You can use an Init container to perform tasks before the rest of a pod is deployed.

Apart from performing specific tasks on nodes, pods, and containers, you can work with the overall OpenShift Container Platform cluster to keep the cluster efficient and the application pods highly available.

## 1.4. ABOUT AUTOSCALING PODS ON A NODE

OpenShift Container Platform offers three tools that you can use to automatically scale the number of pods on your nodes and the resources allocated to pods.

### Horizontal Pod Autoscaler

The Horizontal Pod Autoscaler (HPA) can automatically increase or decrease the scale of a replication controller or deployment configuration, based on metrics collected from the pods that belong to that replication controller or deployment configuration.

For more information, see [Automatically scaling pods with the horizontal pod autoscaler](#) .

### Custom Metrics Autoscaler

The Custom Metrics Autoscaler can automatically increase or decrease the number of pods for a deployment, stateful set, custom resource, or job based on custom metrics that are not based only on CPU or memory.

For more information, see [Custom Metrics Autoscaler Operator overview](#) .

### Vertical Pod Autoscaler

The Vertical Pod Autoscaler (VPA) can automatically review the historic and current CPU and memory resources for containers in pods and can update the resource limits and requests based on the usage values it learns.

For more information, see [Automatically adjust pod resource levels with the vertical pod autoscaler](#) .

## 1.5. GLOSSARY OF COMMON TERMS FOR OPENSIFT CONTAINER PLATFORM NODES

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

### Container

It is a lightweight and executable image that comprises software and all its dependencies. Containers virtualize the operating system, as a result, you can run containers anywhere from a data center to a public or private cloud to even a developer's laptop.

### Daemon set

Ensures that a replica of the pod runs on eligible nodes in an OpenShift Container Platform cluster.

### egress

The process of data sharing externally through a network's outbound traffic from a pod.

### garbage collection

The process of cleaning up cluster resources, such as terminated containers and images that are not referenced by any running pods.

### Horizontal Pod Autoscaler(HPA)

Implemented as a Kubernetes API resource and a controller. You can use the HPA to specify the minimum and maximum number of pods that you want to run. You can also specify the CPU or memory utilization that your pods should target. The HPA scales out and scales in pods when a given CPU or memory threshold is crossed.

### Ingress

Incoming traffic to a pod.

### Job

A process that runs to completion. A job creates one or more pod objects and ensures that the specified pods are successfully completed.

### Labels

You can use labels, which are key-value pairs, to organise and select subsets of objects, such as a pod.

### Node

A worker machine in the OpenShift Container Platform cluster. A node can be either be a virtual machine (VM) or a physical machine.

### Node Tuning Operator

You can use the Node Tuning Operator to manage node-level tuning by using the TuneD daemon. It ensures custom tuning specifications are passed to all containerized TuneD daemons running in the cluster in the format that the daemons understand. The daemons run on all nodes in the cluster, one

per node.

### **Self Node Remediation Operator**

The Operator runs on the cluster nodes and identifies and reboots nodes that are unhealthy.

### **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.

### **Toleration**

Indicates that the pod is allowed (but not required) to be scheduled on nodes or node groups with matching taints. You can use tolerations to enable the scheduler to schedule pods with matching taints.

### **Taint**

A core object that comprises a key,value, and effect. Taints and tolerations work together to ensure that pods are not scheduled on irrelevant nodes.

## CHAPTER 2. WORKING WITH PODS

### 2.1. USING PODS

A *pod* is one or more containers deployed together on one host, and the smallest compute unit that can be defined, deployed, and managed.

#### 2.1.1. Understanding pods

Pods are the rough equivalent of a machine instance (physical or virtual) to a Container. Each pod is allocated its own internal IP address, therefore owning its entire port space, and containers within pods can share their local storage and networking.

Pods have a lifecycle; they are defined, then they are assigned to run on a node, then they run until their container(s) exit or they are removed for some other reason. Pods, depending on policy and exit code, might be removed after exiting, or can be retained to enable access to the logs of their containers.

OpenShift Container Platform treats pods as largely immutable; changes cannot be made to a pod definition while it is running. OpenShift Container Platform implements changes by terminating an existing pod and recreating it with modified configuration, base image(s), or both. Pods are also treated as expendable, and do not maintain state when recreated. Therefore pods should usually be managed by higher-level controllers, rather than directly by users.



#### NOTE

For the maximum number of pods per OpenShift Container Platform node host, see the Cluster Limits.



#### WARNING

Bare pods that are not managed by a replication controller will be not rescheduled upon node disruption.

#### 2.1.2. Example pod configurations

OpenShift Container Platform leverages the Kubernetes concept of a *pod*, which is one or more containers deployed together on one host, and the smallest compute unit that can be defined, deployed, and managed.

The following is an example definition of a pod. It demonstrates many features of pods, most of which are discussed in other topics and thus only briefly mentioned here:

#### Pod object definition (YAML)

```
kind: Pod
apiVersion: v1
metadata:
  name: example
  labels:
```



```

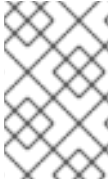
environment: production
app: abc ❶
spec:
  restartPolicy: Always ❷
  securityContext: ❸
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers: ❹
    - name: abc
      args:
        - sleep
        - "1000000"
      volumeMounts: ❺
        - name: cache-volume
          mountPath: /cache ❻
      image: registry.access.redhat.com/ubi7/ubi-init:latest ❼
      securityContext:
        allowPrivilegeEscalation: false
        runAsNonRoot: true
      capabilities:
        drop: ["ALL"]
      resources:
        limits:
          memory: "100Mi"
          cpu: "1"
        requests:
          memory: "100Mi"
          cpu: "1"
  volumes: ❽
    - name: cache-volume
      emptyDir:
        sizeLimit: 500Mi

```

- ❶ Pods can be "tagged" with one or more labels, which can then be used to select and manage groups of pods in a single operation. The labels are stored in key/value format in the **metadata** hash.
- ❷ The pod restart policy with possible values **Always**, **OnFailure**, and **Never**. The default value is **Always**.
- ❸ OpenShift Container Platform defines a security context for containers which specifies whether they are allowed to run as privileged containers, run as a user of their choice, and more. The default context is very restrictive but administrators can modify this as needed.
- ❹ **containers** specifies an array of one or more container definitions.
- ❺ The container specifies where external storage volumes are mounted within the container.
- ❻ Specify the volumes to provide for the pod. Volumes mount at the specified path. 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`.
- ❼ Each container in the pod is instantiated from its own container image.

- 8 The pod defines storage volumes that are available to its container(s) to use.

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?](#).



#### NOTE

This pod definition does not include attributes that are filled by OpenShift Container Platform automatically after the pod is created and its lifecycle begins. The [Kubernetes pod documentation](#) has details about the functionality and purpose of pods.

### 2.1.3. Additional resources

- For more information on pods and storage see [Understanding persistent storage](#) and [Understanding ephemeral storage](#).

## 2.2. VIEWING PODS

As an administrator, you can view the pods in your cluster and to determine the health of those pods and the cluster as a whole.

### 2.2.1. About pods

OpenShift Container Platform leverages the Kubernetes concept of a *pod*, which is one or more containers deployed together on one host, and the smallest compute unit that can be defined, deployed, and managed. Pods are the rough equivalent of a machine instance (physical or virtual) to a container.

You can view a list of pods associated with a specific project or view usage statistics about pods.

### 2.2.2. Viewing pods in a project

You can view a list of pods associated with the current project, including the number of replica, the current status, number or restarts and the age of the pod.

#### Procedure

To view the pods in a project:

1. Change to the project:

```
$ oc project <project-name>
```

2. Run the following command:

```
$ oc get pods
```

For example:

```
$ oc get pods
```

### Example output

```

NAME                READY STATUS  RESTARTS  AGE
console-698d866b78-bnshf 1/1   Running  2         165m
console-698d866b78-m87pm 1/1   Running  2         165m

```

Add the **-o wide** flags to view the pod IP address and the node where the pod is located.

```
$ oc get pods -o wide
```

### Example output

```

NAME                READY STATUS  RESTARTS  AGE  IP             NODE
NOMINATED NODE
console-698d866b78-bnshf 1/1   Running  2     166m  10.128.0.24  ip-10-0-152-71.ec2.internal <none>
console-698d866b78-m87pm 1/1   Running  2     166m  10.129.0.23  ip-10-0-173-237.ec2.internal <none>

```

## 2.2.3. Viewing pod usage statistics

You can display usage statistics about pods, which provide the runtime environments for containers. These usage statistics include CPU, memory, and storage consumption.

### Prerequisites

- You must have **cluster-reader** permission to view the usage statistics.
- Metrics must be installed to view the usage statistics.

### Procedure

To view the usage statistics:

1. Run the following command:

```
$ oc adm top pods
```

For example:

```
$ oc adm top pods -n openshift-console
```

### Example output

```

NAME                CPU(cores)  MEMORY(bytes)
console-7f58c69899-q8c8k  0m          22Mi
console-7f58c69899-xhbgg  0m          25Mi
downloads-594fccc94-bcck8  3m          18Mi
downloads-594fccc94-kv4p6  2m          15Mi

```

2. Run the following command to view the usage statistics for pods with labels:

```
$ oc adm top pod --selector="
```

-

You must choose the selector (label query) to filter on. Supports `=`, `==`, and `!=`.

For example:

```
$ oc adm top pod --selector='name=my-pod'
```

## 2.2.4. Viewing resource logs

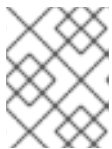
You can view the log for various resources in the OpenShift CLI (**oc**) and web console. Logs read from the tail, or end, of the log.

### Prerequisites

- Access to the OpenShift CLI (**oc**).

### Procedure (UI)

1. In the OpenShift Container Platform console, navigate to **Workloads** → **Pods** or navigate to the pod through the resource you want to investigate.



#### NOTE

Some resources, such as builds, do not have pods to query directly. In such instances, you can locate the **Logs** link on the **Details** page for the resource.

2. Select a project from the drop-down menu.
3. Click the name of the pod you want to investigate.
4. Click **Logs**.

### Procedure (CLI)

- View the log for a specific pod:

```
$ oc logs -f <pod_name> -c <container_name>
```

where:

**-f**

Optional: Specifies that the output follows what is being written into the logs.

**<pod\_name>**

Specifies the name of the pod.

**<container\_name>**

Optional: Specifies the name of a container. When a pod has more than one container, you must specify the container name.

For example:

```
$ oc logs ruby-58cd97df55-mww7r
```

-

```
$ oc logs -f ruby-57f7f4855b-znl92 -c ruby
```

The contents of log files are printed out.

- View the log for a specific resource:

```
$ oc logs <object_type>/<resource_name> 1
```

**1** Specifies the resource type and name.

For example:

```
$ oc logs deployment/ruby
```

The contents of log files are printed out.

## 2.3. CONFIGURING AN OPENSIFT CONTAINER PLATFORM CLUSTER FOR PODS

As an administrator, you can create and maintain an efficient cluster for pods.

By keeping your cluster efficient, you can provide a better environment for your developers using such tools as what a pod does when it exits, ensuring that the required number of pods is always running, when to restart pods designed to run only once, limit the bandwidth available to pods, and how to keep pods running during disruptions.

### 2.3.1. Configuring how pods behave after restart

A pod restart policy determines how OpenShift Container Platform responds when Containers in that pod exit. The policy applies to all Containers in that pod.

The possible values are:

- **Always** - Tries restarting a successfully exited Container on the pod continuously, with an exponential back-off delay (10s, 20s, 40s) capped at 5 minutes. The default is **Always**.
- **OnFailure** - Tries restarting a failed Container on the pod with an exponential back-off delay (10s, 20s, 40s) capped at 5 minutes.
- **Never** - Does not try to restart exited or failed Containers on the pod. Pods immediately fail and exit.

After the pod is bound to a node, the pod will never be bound to another node. This means that a controller is necessary in order for a pod to survive node failure:

Condition	Controller Type	Restart Policy
Pods that are expected to terminate (such as batch computations)	Job	<b>OnFailure</b> or <b>Never</b>

Condition	Controller Type	Restart Policy
Pods that are expected to not terminate (such as web servers)	Replication controller	<b>Always.</b>
Pods that must run one-per-machine	Daemon set	Any

If a Container on a pod fails and the restart policy is set to **OnFailure**, the pod stays on the node and the Container is restarted. If you do not want the Container to restart, use a restart policy of **Never**.

If an entire pod fails, OpenShift Container Platform starts a new pod. Developers must address the possibility that applications might be restarted in a new pod. In particular, applications must handle temporary files, locks, incomplete output, and so forth caused by previous runs.



#### NOTE

Kubernetes architecture expects reliable endpoints from cloud providers. When a cloud provider is down, the kubelet prevents OpenShift Container Platform from restarting.

If the underlying cloud provider endpoints are not reliable, do not install a cluster using cloud provider integration. Install the cluster as if it was in a no-cloud environment. It is not recommended to toggle cloud provider integration on or off in an installed cluster.

For details on how OpenShift Container Platform uses restart policy with failed Containers, see the [Example States](#) in the Kubernetes documentation.

### 2.3.2. Limiting the bandwidth available to pods

You can apply quality-of-service traffic shaping to a pod and effectively limit its available bandwidth. Egress traffic (from the pod) is handled by policing, which simply drops packets in excess of the configured rate. Ingress traffic (to the pod) is handled by shaping queued packets to effectively handle data. The limits you place on a pod do not affect the bandwidth of other pods.

#### Procedure

To limit the bandwidth on a pod:

1. Write an object definition JSON file, and specify the data traffic speed using **kubernetes.io/ingress-bandwidth** and **kubernetes.io/egress-bandwidth** annotations. For example, to limit both pod egress and ingress bandwidth to 10M/s:

#### Limited Pod object definition

```
{
  "kind": "Pod",
  "spec": {
    "containers": [
      {
        "image": "openshift/hello-openshift",
        "name": "hello-openshift"
      }
    ]
  }
}
```

```

    },
    "apiVersion": "v1",
    "metadata": {
      "name": "iperf-slow",
      "annotations": {
        "kubernetes.io/ingress-bandwidth": "10M",
        "kubernetes.io/egress-bandwidth": "10M"
      }
    }
  }
}

```

2. Create the pod using the object definition:

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

### 2.3.3. Understanding how to use pod disruption budgets to specify the number of pods that must be up

A *pod disruption budget* allows the specification of safety constraints on pods during operations, such as draining a node for maintenance.

**PodDisruptionBudget** is an API object that specifies the minimum number or percentage of replicas that must be up at a time. Setting these in projects can be helpful during node maintenance (such as scaling a cluster down or a cluster upgrade) and is only honored on voluntary evictions (not on node failures).

A **PodDisruptionBudget** object's configuration consists of the following key parts:

- A label selector, which is a label query over a set of pods.
- An availability level, which specifies the minimum number of pods that must be available simultaneously, either:
  - **minAvailable** is the number of pods must always be available, even during a disruption.
  - **maxUnavailable** is the number of pods can be unavailable during a disruption.



#### NOTE

**Available** refers to the number of pods that has condition **Ready=True**. **Ready=True** refers to the pod that is able to serve requests and should be added to the load balancing pools of all matching services.

A **maxUnavailable** of **0%** or **0** or a **minAvailable** of **100%** or equal to the number of replicas is permitted but can block nodes from being drained.

**WARNING**

The default setting for **maxUnavailable** is **1** for all the machine config pools in OpenShift Container Platform. It is recommended to not change this value and update one control plane node at a time. Do not change this value to **3** for the control plane pool.

You can check for pod disruption budgets across all projects with the following:

```
$ oc get poddisruptionbudget --all-namespaces
```

**NOTE**

The following example contains some values that are specific to OpenShift Container Platform on AWS.

**Example output**

NAMESPACE	NAME	MIN AVAILABLE	MAX UNAVAILABLE
ALLOWED DISRUPTIONS	AGE		
openshift-apiserver	openshift-apiserver-pdb	N/A	1
121m			1
openshift-cloud-controller-manager	aws-cloud-controller-manager	1	N/A
125m			1
openshift-cloud-credential-operator	pod-identity-webhook	1	N/A
117m			1
openshift-cluster-csi-drivers	aws-ebs-csi-driver-controller-pdb	N/A	1
121m			1
openshift-cluster-storage-operator	csi-snapshot-controller-pdb	N/A	1
122m			1
openshift-cluster-storage-operator	csi-snapshot-webhook-pdb	N/A	1
122m			1
openshift-console	console	N/A	1
116m			1
#...			

The **PodDisruptionBudget** is considered healthy when there are at least **minAvailable** pods running in the system. Every pod above that limit can be evicted.

**NOTE**

Depending on your pod priority and preemption settings, lower-priority pods might be removed despite their pod disruption budget requirements.

**2.3.3.1. Specifying the number of pods that must be up with pod disruption budgets**

You can use a **PodDisruptionBudget** object to specify the minimum number or percentage of replicas that must be up at a time.



## Procedure

To configure a pod disruption budget:

1. Create a YAML file with the an object definition similar to the following:

```
apiVersion: policy/v1 1
kind: PodDisruptionBudget
metadata:
  name: my-pdb
spec:
  minAvailable: 2 2
  selector: 3
    matchLabels:
      name: my-pod
```

- 1** **PodDisruptionBudget** is part of the **policy/v1** API group.
- 2** The minimum number of pods that must be available simultaneously. This can be either an integer or a string specifying a percentage, for example, **20%**.
- 3** A label query over a set of resources. The result of **matchLabels** and **matchExpressions** are logically conjoined. Leave this parameter blank, for example **selector {}**, to select all pods in the project.

Or:

```
apiVersion: policy/v1 1
kind: PodDisruptionBudget
metadata:
  name: my-pdb
spec:
  maxUnavailable: 25% 2
  selector: 3
    matchLabels:
      name: my-pod
```

- 1** **PodDisruptionBudget** is part of the **policy/v1** API group.
- 2** The maximum number of pods that can be unavailable simultaneously. This can be either an integer or a string specifying a percentage, for example, **20%**.
- 3** A label query over a set of resources. The result of **matchLabels** and **matchExpressions** are logically conjoined. Leave this parameter blank, for example **selector {}**, to select all pods in the project.

2. Run the following command to add the object to project:

```
$ oc create -f </path/to/file> -n <project_name>
```

### 2.3.3.2. Specifying the eviction policy for unhealthy pods

When you use pod disruption budgets (PDBs) to specify how many pods must be available simultaneously, you can also define the criteria for how unhealthy pods are considered for eviction.

You can choose one of the following policies:

### IfHealthyBudget

Running pods that are not yet healthy can be evicted only if the guarded application is not disrupted.

### AlwaysAllow

Running pods that are not yet healthy can be evicted regardless of whether the criteria in the pod disruption budget is met. This policy can help evict malfunctioning applications, such as ones with pods stuck in the **CrashLoopBackOff** state or failing to report the **Ready** status.



#### NOTE

It is recommended to set the **unhealthyPodEvictionPolicy** field to **AlwaysAllow** in the **PodDisruptionBudget** object to support the eviction of misbehaving applications during a node drain. The default behavior is to wait for the application pods to become healthy before the drain can proceed.

### Procedure

1. Create a YAML file that defines a **PodDisruptionBudget** object and specify the unhealthy pod eviction policy:

#### Example pod-disruption-budget.yaml file

```
apiVersion: policy/v1
kind: PodDisruptionBudget
metadata:
  name: my-pdb
spec:
  minAvailable: 2
  selector:
    matchLabels:
      name: my-pod
  unhealthyPodEvictionPolicy: AlwaysAllow 1
```

- 1** Choose either **IfHealthyBudget** or **AlwaysAllow** as the unhealthy pod eviction policy. The default is **IfHealthyBudget** when the **unhealthyPodEvictionPolicy** field is empty.

2. Create the **PodDisruptionBudget** object by running the following command:

```
$ oc create -f pod-disruption-budget.yaml
```

With a PDB that has the **AlwaysAllow** unhealthy pod eviction policy set, you can now drain nodes and evict the pods for a malfunctioning application guarded by this PDB.

### Additional resources

- [Enabling features using feature gates](#)

- [Unhealthy Pod Eviction Policy](#) in the Kubernetes documentation

### 2.3.4. Preventing pod removal using critical pods

There are a number of core components that are critical to a fully functional cluster, but, run on a regular cluster node rather than the master. A cluster might stop working properly if a critical add-on is evicted.

Pods marked as critical are not allowed to be evicted.

#### Procedure

To make a pod critical:

1. Create a **Pod** spec or edit existing pods to include the **system-cluster-critical** priority class:

```
apiVersion: v1
kind: Pod
metadata:
  name: my-pdb
spec:
  template:
    metadata:
      name: critical-pod
      priorityClassName: system-cluster-critical 1
# ...
```

- 1 Default priority class for pods that should never be evicted from a node.

Alternatively, you can specify **system-node-critical** for pods that are important to the cluster but can be removed if necessary.

2. Create the pod:

```
$ oc create -f <file-name>.yaml
```

### 2.3.5. Reducing pod timeouts when using persistent volumes with high file counts

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

This can occur because, when volumes are mounted, OpenShift Container Platform recursively changes the ownership and permissions of the contents of each volume in order to match the **fsGroup** specified in a pod's **securityContext**. For large volumes, checking and changing the ownership and permissions can be time consuming, resulting in a very slow pod startup.

You can reduce this delay by applying one of the following workarounds:

- Use a security context constraint (SCC) to skip the SELinux relabeling for a volume.
- Use the **fsGroupChangePolicy** field inside an SCC to control the way that OpenShift Container Platform checks and manages ownership and permissions for a volume.
- Use the Cluster Resource Override Operator to automatically apply an SCC to skip the SELinux relabeling.
- Use a runtime class to skip the SELinux relabeling for a volume.

For 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?](#).

## 2.4. AUTOMATICALLY SCALING PODS WITH THE HORIZONTAL POD AUTOSCALER

As a developer, you can use a horizontal pod autoscaler (HPA) to specify how OpenShift Container Platform should automatically increase or decrease the scale of a replication controller or deployment configuration, based on metrics collected from the pods that belong to that replication controller or deployment configuration. You can create an HPA for any deployment, deployment config, replica set, replication controller, or stateful set.

For information on scaling pods based on custom metrics, see [Automatically scaling pods based on custom metrics](#).



### NOTE

It is recommended to use a **Deployment** object or **ReplicaSet** object unless you need a specific feature or behavior provided by other objects. For more information on these objects, see [Understanding deployments](#).

### 2.4.1. Understanding horizontal pod autoscalers

You can create a horizontal pod autoscaler to specify the minimum and maximum number of pods you want to run, as well as the CPU utilization or memory utilization your pods should target.

After you create a horizontal pod autoscaler, OpenShift Container Platform begins to query the CPU and/or memory resource metrics on the pods. When these metrics are available, the horizontal pod autoscaler computes the ratio of the current metric utilization with the desired metric utilization, and scales up or down accordingly. The query and scaling occurs at a regular interval, but can take one to two minutes before metrics become available.

For replication controllers, this scaling corresponds directly to the replicas of the replication controller. For deployment configurations, scaling corresponds directly to the replica count of the deployment configuration. Note that autoscaling applies only to the latest deployment in the **Complete** phase.

OpenShift Container Platform automatically accounts for resources and prevents unnecessary autoscaling during resource spikes, such as during start up. Pods in the **unready** state have **0 CPU** usage when scaling up and the autoscaler ignores the pods when scaling down. Pods without known metrics have **0% CPU** usage when scaling up and **100% CPU** when scaling down. This allows for more stability during the HPA decision. To use this feature, you must configure readiness checks to determine if a new pod is ready for use.

To use horizontal pod autoscalers, your cluster administrator must have properly configured cluster metrics.

#### 2.4.1.1. Supported metrics

The following metrics are supported by horizontal pod autoscalers:

**Table 2.1. Metrics**

Metric	Description	API version
CPU utilization	Number of CPU cores used. Can be used to calculate a percentage of the pod's requested CPU.	<b>autoscaling/v1, autoscaling/v2</b>
Memory utilization	Amount of memory used. Can be used to calculate a percentage of the pod's requested memory.	<b>autoscaling/v2</b>

## IMPORTANT

For memory-based autoscaling, memory usage must increase and decrease proportionally to the replica count. On average:

- An increase in replica count must lead to an overall decrease in memory (working set) usage per-pod.
- A decrease in replica count must lead to an overall increase in per-pod memory usage.

Use the OpenShift Container Platform web console to check the memory behavior of your application and ensure that your application meets these requirements before using memory-based autoscaling.

The following example shows autoscaling for the **image-registry Deployment** object. The initial deployment requires 3 pods. The HPA object increases the minimum to 5. If CPU usage on the pods reaches 75%, the pods increase to 7:

```
$ oc autoscale deployment/image-registry --min=5 --max=7 --cpu-percent=75
```

## Example output

```
horizontalpodautoscaler.autoscaling/image-registry autoscaled
```

## Sample HPA for the image-registry Deployment object with minReplicas set to 3

```
apiVersion: autoscaling/v1
kind: HorizontalPodAutoscaler
metadata:
  name: image-registry
  namespace: default
spec:
  maxReplicas: 7
  minReplicas: 3
  scaleTargetRef:
    apiVersion: apps/v1
    kind: Deployment
    name: image-registry
    targetCPUUtilizationPercentage: 75
```

```
status:
  currentReplicas: 5
  desiredReplicas: 0
```

1. View the new state of the deployment:

```
$ oc get deployment image-registry
```

There are now 5 pods in the deployment:

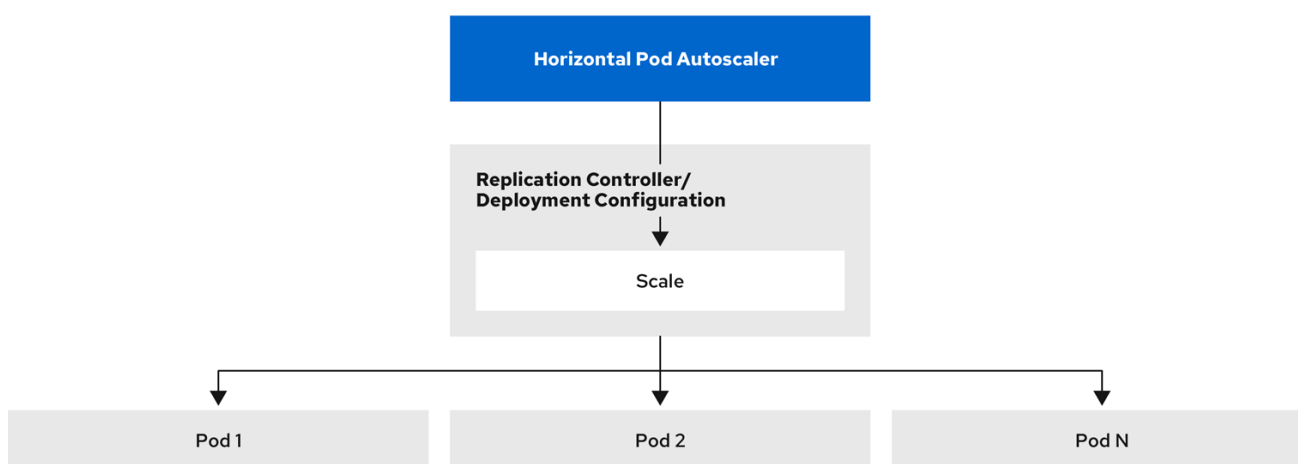
### Example output

```
NAME           REVISION  DESIRED  CURRENT  TRIGGERED BY
image-registry 1         5        5        config
```

## 2.4.2. How does the HPA work?

The horizontal pod autoscaler (HPA) extends the concept of pod auto-scaling. The HPA lets you create and manage a group of load-balanced nodes. The HPA automatically increases or decreases the number of pods when a given CPU or memory threshold is crossed.

Figure 2.1. High level workflow of the HPA



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The HPA is an API resource in the Kubernetes autoscaling API group. The autoscaler works as a control loop with a default of 15 seconds for the sync period. During this period, the controller manager queries the CPU, memory utilization, or both, against what is defined in the YAML file for the HPA. The controller manager obtains the utilization metrics from the resource metrics API for per-pod resource metrics like CPU or memory, for each pod that is targeted by the HPA.

If a utilization value target is set, the controller calculates the utilization value as a percentage of the equivalent resource request on the containers in each pod. The controller then takes the average of utilization across all targeted pods and produces a ratio that is used to scale the number of desired replicas. The HPA is configured to fetch metrics from **metrics.k8s.io**, which is provided by the metrics server. Because of the dynamic nature of metrics evaluation, the number of replicas can fluctuate during scaling for a group of replicas.

**NOTE**

To implement the HPA, all targeted pods must have a resource request set on their containers.

### 2.4.3. About requests and limits

The scheduler uses the resource request that you specify for containers in a pod, to decide which node to place the pod on. The kubelet enforces the resource limit that you specify for a container to ensure that the container is not allowed to use more than the specified limit. The kubelet also reserves the request amount of that system resource specifically for that container to use.

#### How to use resource metrics?

In the pod specifications, you must specify the resource requests, such as CPU and memory. The HPA uses this specification to determine the resource utilization and then scales the target up or down.

For example, the HPA object uses the following metric source:

```
type: Resource
resource:
  name: cpu
  target:
    type: Utilization
    averageUtilization: 60
```

In this example, the HPA keeps the average utilization of the pods in the scaling target at 60%. Utilization is the ratio between the current resource usage to the requested resource of the pod.

### 2.4.4. Best practices

#### All pods must have resource requests configured

The HPA makes a scaling decision based on the observed CPU or memory utilization values of pods in an OpenShift Container Platform cluster. Utilization values are calculated as a percentage of the resource requests of each pod. Missing resource request values can affect the optimal performance of the HPA.

#### Configure the cool down period

During horizontal pod autoscaling, there might be a rapid scaling of events without a time gap. Configure the cool down period to prevent frequent replica fluctuations. You can specify a cool down period by configuring the **stabilizationWindowSeconds** field. The stabilization window is used to restrict the fluctuation of replicas count when the metrics used for scaling keep fluctuating. The autoscaling algorithm uses this window to infer a previous desired state and avoid unwanted changes to workload scale.

For example, a stabilization window is specified for the **scaleDown** field:

```
behavior:
  scaleDown:
    stabilizationWindowSeconds: 300
```

In the above example, all desired states for the past 5 minutes are considered. This approximates a rolling maximum, and avoids having the scaling algorithm frequently remove pods only to trigger recreating an equivalent pod just moments later.

### 2.4.4.1. Scaling policies

The **autoscaling/v2** API allows you to add *scaling policies* to a horizontal pod autoscaler. A scaling policy controls how the OpenShift Container Platform horizontal pod autoscaler (HPA) scales pods. Scaling policies allow you to restrict the rate that HPAs scale pods up or down by setting a specific number or specific percentage to scale in a specified period of time. You can also define a *stabilization window*, which uses previously computed desired states to control scaling if the metrics are fluctuating. You can create multiple policies for the same scaling direction, and determine which policy is used, based on the amount of change. You can also restrict the scaling by timed iterations. The HPA scales pods during an iteration, then performs scaling, as needed, in further iterations.

#### Sample HPA object with a scaling policy

```

apiVersion: autoscaling/v2
kind: HorizontalPodAutoscaler
metadata:
  name: hpa-resource-metrics-memory
  namespace: default
spec:
  behavior:
    scaleDown: 1
      policies: 2
        - type: Pods 3
          value: 4 4
          periodSeconds: 60 5
        - type: Percent
          value: 10 6
          periodSeconds: 60
          selectPolicy: Min 7
          stabilizationWindowSeconds: 300 8
    scaleUp: 9
      policies:
        - type: Pods
          value: 5 10
          periodSeconds: 70
        - type: Percent
          value: 12 11
          periodSeconds: 80
          selectPolicy: Max
          stabilizationWindowSeconds: 0
  ...

```

- 1 Specifies the direction for the scaling policy, either **scaleDown** or **scaleUp**. This example creates a policy for scaling down.
- 2 Defines the scaling policy.
- 3 Determines if the policy scales by a specific number of pods or a percentage of pods during each iteration. The default value is **pods**.
- 4 Limits the amount of scaling, either the number of pods or percentage of pods, during each iteration. There is no default value for scaling down by number of pods.
- 5 Determines the length of a scaling iteration. The default value is **15** seconds.



- 6 The default value for scaling down by percentage is 100%.
- 7 Determines which policy to use first, if multiple policies are defined. Specify **Max** to use the policy that allows the highest amount of change, **Min** to use the policy that allows the lowest amount of change, or **Disabled** to prevent the HPA from scaling in that policy direction. The default value is **Max**.
- 8 Determines the time period the HPA should look back at desired states. The default value is **0**.
- 9 This example creates a policy for scaling up.
- 10 Limits the amount of scaling up by the number of pods. The default value for scaling up the number of pods is 4%.
- 11 Limits the amount of scaling up by the percentage of pods. The default value for scaling up by percentage is 100%.

### Example policy for scaling down

```

apiVersion: autoscaling/v2
kind: HorizontalPodAutoscaler
metadata:
  name: hpa-resource-metrics-memory
  namespace: default
spec:
  ...
  minReplicas: 20
  ...
  behavior:
    scaleDown:
      stabilizationWindowSeconds: 300
      policies:
        - type: Pods
          value: 4
          periodSeconds: 30
        - type: Percent
          value: 10
          periodSeconds: 60
      selectPolicy: Max
    scaleUp:
      selectPolicy: Disabled

```

In this example, when the number of pods is greater than 40, the percent-based policy is used for scaling down, as that policy results in a larger change, as required by the **selectPolicy**.

If there are 80 pod replicas, in the first iteration the HPA reduces the pods by 8, which is 10% of the 80 pods (based on the **type: Percent** and **value: 10** parameters), over one minute (**periodSeconds: 60**). For the next iteration, the number of pods is 72. The HPA calculates that 10% of the remaining pods is 7.2, which it rounds up to 8 and scales down 8 pods. On each subsequent iteration, the number of pods to be scaled is re-calculated based on the number of remaining pods. When the number of pods falls below 40, the pods-based policy is applied, because the pod-based number is greater than the percent-based number. The HPA reduces 4 pods at a time (**type: Pods** and **value: 4**), over 30 seconds (**periodSeconds: 30**), until there are 20 replicas remaining (**minReplicas**).

The **selectPolicy: Disabled** parameter prevents the HPA from scaling up the pods. You can manually scale up by adjusting the number of replicas in the replica set or deployment set, if needed.

If set, you can view the scaling policy by using the **oc edit** command:

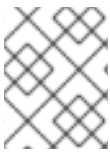
```
$ oc edit hpa hpa-resource-metrics-memory
```

### Example output

```
apiVersion: autoscaling/v1
kind: HorizontalPodAutoscaler
metadata:
  annotations:
    autoscaling.alpha.kubernetes.io/behavior:\
'{"ScaleUp":{"StabilizationWindowSeconds":0,"SelectPolicy":"Max","Policies":\
[{"Type":"Pods","Value":4,"PeriodSeconds":15},{"Type":"Percent","Value":100,"PeriodSeconds":15}],\
"ScaleDown":{"StabilizationWindowSeconds":300,"SelectPolicy":"Min","Policies":\
[{"Type":"Pods","Value":4,"PeriodSeconds":60},{"Type":"Percent","Value":10,"PeriodSeconds":60}]}'
...
```

## 2.4.5. Creating a horizontal pod autoscaler by using the web console

From the web console, you can create a horizontal pod autoscaler (HPA) that specifies the minimum and maximum number of pods you want to run on a **Deployment** or **DeploymentConfig** object. You can also define the amount of CPU or memory usage that your pods should target.



### NOTE

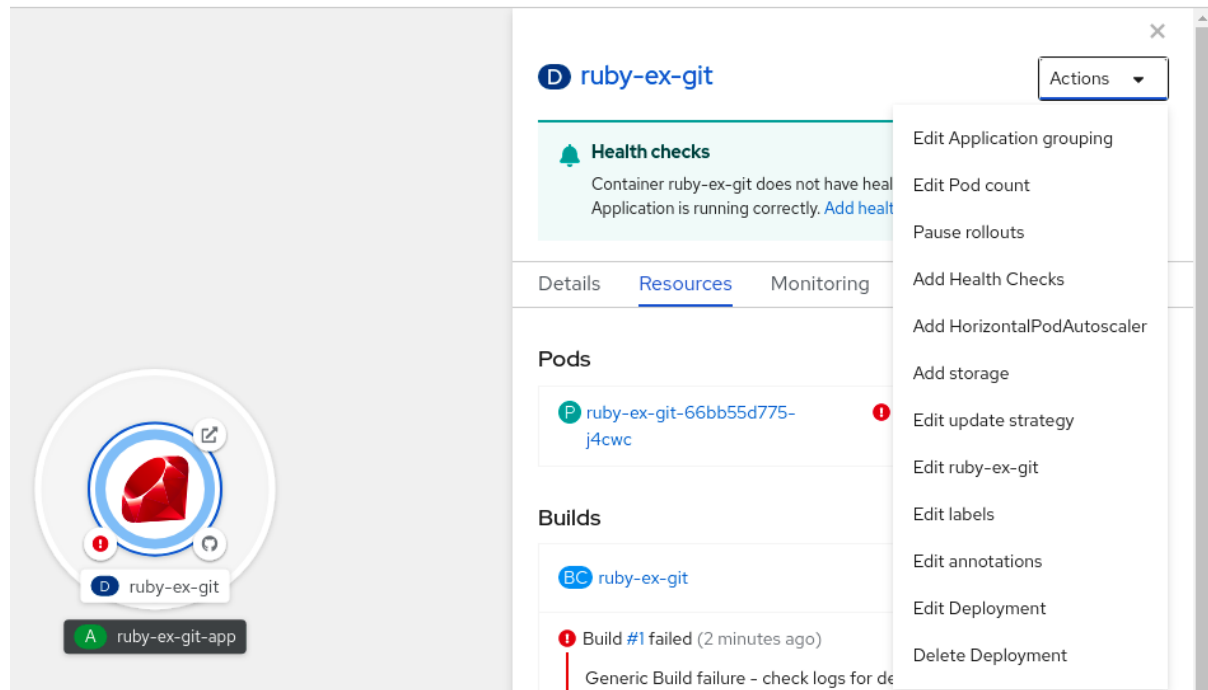
An HPA cannot be added to deployments that are part of an Operator-backed service, Knative service, or Helm chart.

### Procedure

To create an HPA in the web console:

1. In the **Topology** view, click the node to reveal the side pane.
2. From the **Actions** drop-down list, select **Add HorizontalPodAutoscaler** to open the **Add HorizontalPodAutoscaler** form.

Figure 2.2. Add HorizontalPodAutoscaler



3. From the **Add HorizontalPodAutoscaler** form, define the name, minimum and maximum pod limits, the CPU and memory usage, and click **Save**.

**NOTE**

If any of the values for CPU and memory usage are missing, a warning is displayed.

To edit an HPA in the web console:

1. In the **Topology** view, click the node to reveal the side panel.
2. From the **Actions** drop-down list, select **Edit HorizontalPodAutoscaler** to open the **Edit Horizontal Pod Autoscaler** form.
3. From the **Edit Horizontal Pod Autoscaler** form, edit the minimum and maximum pod limits and the CPU and memory usage, and click **Save**.

**NOTE**

While creating or editing the horizontal pod autoscaler in the web console, you can switch from **Form view** to **YAML view**.

To remove an HPA in the web console:

1. In the **Topology** view, click the node to reveal the side panel.
2. From the **Actions** drop-down list, select **Remove HorizontalPodAutoscaler**.
3. In the confirmation pop-up window, click **Remove** to remove the HPA.

## 2.4.6. Creating a horizontal pod autoscaler for CPU utilization by using the CLI

Using the OpenShift Container Platform CLI, you can create a horizontal pod autoscaler (HPA) to automatically scale an existing **Deployment**, **DeploymentConfig**, **ReplicaSet**, **ReplicationController**, or **StatefulSet** object. The HPA scales the pods associated with that object to maintain the CPU usage you specify.



## NOTE

It is recommended to use a **Deployment** object or **ReplicaSet** object unless you need a specific feature or behavior provided by other objects.

The HPA increases and decreases the number of replicas between the minimum and maximum numbers to maintain the specified CPU utilization across all pods.

When autoscaling for CPU utilization, you can use the **oc autoscale** command and specify the minimum and maximum number of pods you want to run at any given time and the average CPU utilization your pods should target. If you do not specify a minimum, the pods are given default values from the OpenShift Container Platform server.

To autoscale for a specific CPU value, create a **HorizontalPodAutoscaler** object with the target CPU and pod limits.

## Prerequisites

To use horizontal pod autoscalers, your cluster administrator must have properly configured cluster metrics. You can use the **oc describe PodMetrics <pod-name>** command to determine if metrics are configured. If metrics are configured, the output appears similar to the following, with **Cpu** and **Memory** displayed under **Usage**.

```
$ oc describe PodMetrics openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
```

## Example output

```
Name:      openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
Namespace: openshift-kube-scheduler
Labels:    <none>
Annotations: <none>
API Version: metrics.k8s.io/v1beta1
Containers:
  Name: wait-for-host-port
  Usage:
    Memory: 0
  Name: scheduler
  Usage:
    Cpu: 8m
    Memory: 45440Ki
Kind: PodMetrics
Metadata:
  Creation Timestamp: 2019-05-23T18:47:56Z
  Self Link: /apis/metrics.k8s.io/v1beta1/namespaces/openshift-kube-scheduler/pods/openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
  Timestamp: 2019-05-23T18:47:56Z
  Window: 1m0s
  Events: <none>
```

## Procedure

To create a horizontal pod autoscaler for CPU utilization:

1. Perform one of the following:

- To scale based on the percent of CPU utilization, create a **HorizontalPodAutoscaler** object for an existing object:

```
$ oc autoscale <object_type>/<name> \ 1
--min <number> \ 2
--max <number> \ 3
--cpu-percent=<percent> 4
```

- Specify the type and name of the object to autoscale. The object must exist and be a **Deployment**, **DeploymentConfig/dc**, **ReplicaSet/rs**, **ReplicationController/rc**, or **StatefulSet**.
- Optionally, specify the minimum number of replicas when scaling down.
- Specify the maximum number of replicas when scaling up.
- Specify the target average CPU utilization over all the pods, represented as a percent of requested CPU. If not specified or negative, a default autoscaling policy is used.

For example, the following command shows autoscaling for the **image-registry Deployment** object. The initial deployment requires 3 pods. The HPA object increases the minimum to 5. If CPU usage on the pods reaches 75%, the pods will increase to 7:

```
$ oc autoscale deployment/image-registry --min=5 --max=7 --cpu-percent=75
```

- To scale for a specific CPU value, create a YAML file similar to the following for an existing object:
  - Create a YAML file similar to the following:

```
apiVersion: autoscaling/v2 1
kind: HorizontalPodAutoscaler
metadata:
  name: cpu-autoscale 2
  namespace: default
spec:
  scaleTargetRef:
    apiVersion: apps/v1 3
    kind: Deployment 4
    name: example 5
  minReplicas: 1 6
  maxReplicas: 10 7
  metrics: 8
  - type: Resource
    resource:
      name: cpu 9
      target:
        type: AverageValue 10
        averageValue: 500m 11
```

- 1 Use the **autoscaling/v2** API.
- 2 Specify a name for this horizontal pod autoscaler object.
- 3 Specify the API version of the object to scale:
  - For a **Deployment, ReplicaSet, StatefulSet** object, use **apps/v1**.
  - For a **ReplicationController**, use **v1**.
  - For a **DeploymentConfig**, use **apps.openshift.io/v1**.
- 4 Specify the type of object. The object must be a **Deployment, DeploymentConfig/dc, ReplicaSet/rs, ReplicationController/rc, or StatefulSet**.
- 5 Specify the name of the object to scale. The object must exist.
- 6 Specify the minimum number of replicas when scaling down.
- 7 Specify the maximum number of replicas when scaling up.
- 8 Use the **metrics** parameter for memory utilization.
- 9 Specify **cpu** for CPU utilization.
- 10 Set to **AverageValue**.
- 11 Set to **averageValue** with the targeted CPU value.

b. Create the horizontal pod autoscaler:

```
$ oc create -f <file-name>.yaml
```

2. Verify that the horizontal pod autoscaler was created:

```
$ oc get hpa cpu-autoscale
```

#### Example output

NAME	REFERENCE	TARGETS	MINPODS	MAXPODS	REPLICAS
cpu-autoscale	Deployment/example	173m/500m	1	10	1

### 2.4.7. Creating a horizontal pod autoscaler object for memory utilization by using the CLI

Using the OpenShift Container Platform CLI, you can create a horizontal pod autoscaler (HPA) to automatically scale an existing **Deployment, DeploymentConfig, ReplicaSet, ReplicationController, or StatefulSet** object. The HPA scales the pods associated with that object to maintain the average memory utilization you specify, either a direct value or a percentage of requested memory.



## NOTE

It is recommended to use a **Deployment** object or **ReplicaSet** object unless you need a specific feature or behavior provided by other objects.

The HPA increases and decreases the number of replicas between the minimum and maximum numbers to maintain the specified memory utilization across all pods.

For memory utilization, you can specify the minimum and maximum number of pods and the average memory utilization your pods should target. If you do not specify a minimum, the pods are given default values from the OpenShift Container Platform server.

## Prerequisites

To use horizontal pod autoscalers, your cluster administrator must have properly configured cluster metrics. You can use the **oc describe PodMetrics <pod-name>** command to determine if metrics are configured. If metrics are configured, the output appears similar to the following, with **Cpu** and **Memory** displayed under **Usage**.

```
$ oc describe PodMetrics openshift-kube-scheduler-ip-10-0-129-223.compute.internal -n openshift-kube-scheduler
```

## Example output

```
Name:      openshift-kube-scheduler-ip-10-0-129-223.compute.internal
Namespace: openshift-kube-scheduler
Labels:    <none>
Annotations: <none>
API Version: metrics.k8s.io/v1beta1
Containers:
  Name: wait-for-host-port
  Usage:
    Cpu: 0
    Memory: 0
  Name: scheduler
  Usage:
    Cpu: 8m
    Memory: 45440Ki
Kind:      PodMetrics
Metadata:
  Creation Timestamp: 2020-02-14T22:21:14Z
  Self Link:         /apis/metrics.k8s.io/v1beta1/namespaces/openshift-kube-scheduler/pods/openshift-kube-scheduler-ip-10-0-129-223.compute.internal
  Timestamp:        2020-02-14T22:21:14Z
  Window:           5m0s
  Events:           <none>
```

## Procedure

To create a horizontal pod autoscaler for memory utilization:

1. Create a YAML file for one of the following:
  - To scale for a specific memory value, create a **HorizontalPodAutoscaler** object similar to the following for an existing object:

```

apiVersion: autoscaling/v2 1
kind: HorizontalPodAutoscaler
metadata:
  name: hpa-resource-metrics-memory 2
  namespace: default
spec:
  scaleTargetRef:
    apiVersion: apps/v1 3
    kind: Deployment 4
    name: example 5
  minReplicas: 1 6
  maxReplicas: 10 7
  metrics: 8
  - type: Resource
    resource:
      name: memory 9
      target:
        type: AverageValue 10
        averageValue: 500Mi 11
  behavior: 12
  scaleDown:
    stabilizationWindowSeconds: 300
    policies:
      - type: Pods
        value: 4
        periodSeconds: 60
      - type: Percent
        value: 10
        periodSeconds: 60
    selectPolicy: Max

```

- 1 Use the **autoscaling/v2** API.
- 2 Specify a name for this horizontal pod autoscaler object.
- 3 Specify the API version of the object to scale:
  - For a **Deployment**, **ReplicaSet**, or **StatefulSet** object, use **apps/v1**.
  - For a **ReplicationController**, use **v1**.
  - For a **DeploymentConfig**, use **apps.openshift.io/v1**.
- 4 Specify the type of object. The object must be a **Deployment**, **DeploymentConfig**, **ReplicaSet**, **ReplicationController**, or **StatefulSet**.
- 5 Specify the name of the object to scale. The object must exist.
- 6 Specify the minimum number of replicas when scaling down.
- 7 Specify the maximum number of replicas when scaling up.
- 8 Use the **metrics** parameter for memory utilization.
- 9 Specify **memory** for memory utilization.



- 10 Set the type to **AverageValue**.
  - 11 Specify **averageValue** and a specific memory value.
  - 12 Optional: Specify a scaling policy to control the rate of scaling up or down.
- To scale for a percentage, create a **HorizontalPodAutoscaler** object similar to the following for an existing object:

```

apiVersion: autoscaling/v2 1
kind: HorizontalPodAutoscaler
metadata:
  name: memory-autoscale 2
  namespace: default
spec:
  scaleTargetRef:
    apiVersion: apps/v1 3
    kind: Deployment 4
    name: example 5
  minReplicas: 1 6
  maxReplicas: 10 7
  metrics: 8
  - type: Resource
    resource:
      name: memory 9
      target:
        type: Utilization 10
        averageUtilization: 50 11
  behavior: 12
  scaleUp:
    stabilizationWindowSeconds: 180
    policies:
      - type: Pods
        value: 6
        periodSeconds: 120
      - type: Percent
        value: 10
        periodSeconds: 120
    selectPolicy: Max

```

- 1 Use the **autoscaling/v2** API.
- 2 Specify a name for this horizontal pod autoscaler object.
- 3 Specify the API version of the object to scale:
  - For a ReplicationController, use **v1**.
  - For a DeploymentConfig, use **apps.openshift.io/v1**.
  - For a Deployment, ReplicaSet, Statefulset object, use **apps/v1**.
- 4 Specify the type of object. The object must be a **Deployment**, **DeploymentConfig**, **ReplicaSet**, **ReplicationController**, or **StatefulSet**.

- 5 Specify the name of the object to scale. The object must exist.
- 6 Specify the minimum number of replicas when scaling down.
- 7 Specify the maximum number of replicas when scaling up.
- 8 Use the **metrics** parameter for memory utilization.
- 9 Specify **memory** for memory utilization.
- 10 Set to **Utilization**.
- 11 Specify **averageUtilization** and a target average memory utilization over all the pods, represented as a percent of requested memory. The target pods must have memory requests configured.
- 12 Optional: Specify a scaling policy to control the rate of scaling up or down.

2. Create the horizontal pod autoscaler:

```
$ oc create -f <file-name>.yaml
```

For example:

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

### Example output

```
horizontalpodautoscaler.autoscaling/hpa-resource-metrics-memory created
```

3. Verify that the horizontal pod autoscaler was created:

```
$ oc get hpa hpa-resource-metrics-memory
```

### Example output

NAME	REFERENCE	TARGETS	MINPODS	MAXPODS
hpa-resource-metrics-memory	Deployment/example	2441216/500Mi	1	10
REPLICAS	AGE			
20m				1

```
$ oc describe hpa hpa-resource-metrics-memory
```

### Example output

```
Name:                hpa-resource-metrics-memory
Namespace:           default
Labels:              <none>
Annotations:         <none>
CreationTimestamp:   Wed, 04 Mar 2020 16:31:37 +0530
Reference:           Deployment/example
Metrics:             ( current / target )
```

```

resource memory on pods: 2441216 / 500Mi
Min replicas:          1
Max replicas:          10
ReplicationController pods: 1 current / 1 desired
Conditions:
  Type           Status Reason           Message
  ----           -
  AbleToScale    True  ReadyForNewScale recommended size matches current size
  ScalingActive  True  ValidMetricFound  the HPA was able to successfully calculate a
replica count from memory resource
  ScalingLimited False DesiredWithinRange the desired count is within the acceptable
range
Events:
  Type           Reason           Age           From           Message
  ----           -
  Normal        SuccessfulRescale 6m34s         horizontal-pod-autoscaler New size: 1;
reason: All metrics below target

```

### 2.4.8. Understanding horizontal pod autoscaler status conditions by using the CLI

You can use the status conditions set to determine whether or not the horizontal pod autoscaler (HPA) is able to scale and whether or not it is currently restricted in any way.

The HPA status conditions are available with the **v2** version of the autoscaling API.

The HPA responds with the following status conditions:

- The **AbleToScale** condition indicates whether HPA is able to fetch and update metrics, as well as whether any backoff-related conditions could prevent scaling.
  - A **True** condition indicates scaling is allowed.
  - A **False** condition indicates scaling is not allowed for the reason specified.
- The **ScalingActive** condition indicates whether the HPA is enabled (for example, the replica count of the target is not zero) and is able to calculate desired metrics.
  - A **True** condition indicates metrics is working properly.
  - A **False** condition generally indicates a problem with fetching metrics.
- The **ScalingLimited** condition indicates that the desired scale was capped by the maximum or minimum of the horizontal pod autoscaler.
  - A **True** condition indicates that you need to raise or lower the minimum or maximum replica count in order to scale.
  - A **False** condition indicates that the requested scaling is allowed.

```
$ oc describe hpa cm-test
```

#### Example output

```

Name:          cm-test
Namespace:     prom
Labels:        <none>

```

```

Annotations:          <none>
CreationTimestamp:    Fri, 16 Jun 2017 18:09:22 +0000
Reference:            ReplicationController/cm-test
Metrics:              ( current / target )
  "http_requests" on pods: 66m / 500m
Min replicas:         1
Max replicas:         4
ReplicationController pods: 1 current / 1 desired
Conditions: 1
  Type           Status Reason           Message
  ----           -
  AbleToScale    True   ReadyForNewScale the last scale time was sufficiently old
as to warrant a new scale
  ScalingActive  True   ValidMetricFound  the HPA was able to successfully
calculate a replica count from pods metric http_request
  ScalingLimited False  DesiredWithinRange the desired replica count is within the
acceptable range
Events:

```

- 1** The horizontal pod autoscaler status messages.

The following is an example of a pod that is unable to scale:

### Example output

```

Conditions:
  Type           Status Reason           Message
  ----           -
  AbleToScale    False  FailedGetScale    the HPA controller was unable to get the target's current
scale: no matches for kind "ReplicationController" in group "apps"
Events:
  Type           Reason          Age           From           Message
  ----           -
  Warning        FailedGetScale  6s (x3 over 36s) horizontal-pod-autoscaler no matches for kind
"ReplicationController" in group "apps"

```

The following is an example of a pod that could not obtain the needed metrics for scaling:

### Example output

```

Conditions:
  Type           Status Reason           Message
  ----           -
  AbleToScale    True   SucceededGetScale the HPA controller was able to get the target's
current scale
  ScalingActive  False  FailedGetResourceMetric the HPA was unable to compute the replica
count: failed to get cpu utilization: unable to get metrics for resource cpu: no metrics returned from
resource metrics API

```

The following is an example of a pod where the requested autoscaling was less than the required minimums:

### Example output

■

Conditions:

Type	Status	Reason	Message
AbleToScale	True	ReadyForNewScale	the last scale time was sufficiently old as to warrant a new scale
ScalingActive	True	ValidMetricFound	the HPA was able to successfully calculate a replica count from pods metric http_request
ScalingLimited	False	DesiredWithinRange	the desired replica count is within the acceptable range

### 2.4.8.1. Viewing horizontal pod autoscaler status conditions by using the CLI

You can view the status conditions set on a pod by the horizontal pod autoscaler (HPA).



#### NOTE

The horizontal pod autoscaler status conditions are available with the **v2** version of the autoscaling API.

### Prerequisites

To use horizontal pod autoscalers, your cluster administrator must have properly configured cluster metrics. You can use the **oc describe PodMetrics <pod-name>** command to determine if metrics are configured. If metrics are configured, the output appears similar to the following, with **Cpu** and **Memory** displayed under **Usage**.

```
$ oc describe PodMetrics openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
```

### Example output

```
Name:      openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
Namespace: openshift-kube-scheduler
Labels:    <none>
Annotations: <none>
API Version: metrics.k8s.io/v1beta1
Containers:
  Name: wait-for-host-port
  Usage:
    Memory: 0
  Name: scheduler
  Usage:
    Cpu: 8m
    Memory: 45440Ki
Kind:      PodMetrics
Metadata:
  Creation Timestamp: 2019-05-23T18:47:56Z
  Self Link:          /apis/metrics.k8s.io/v1beta1/namespaces/openshift-kube-scheduler/pods/openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
  Timestamp:         2019-05-23T18:47:56Z
  Window:            1m0s
  Events:            <none>
```

### Procedure

To view the status conditions on a pod, use the following command with the name of the pod:

```
$ oc describe hpa <pod-name>
```

For example:

```
$ oc describe hpa cm-test
```

The conditions appear in the **Conditions** field in the output.

### Example output

```
Name:          cm-test
Namespace:     prom
Labels:        <none>
Annotations:   <none>
CreationTimestamp:  Fri, 16 Jun 2017 18:09:22 +0000
Reference:     ReplicationController/cm-test
Metrics:       ( current / target )
"http_requests" on pods:  66m / 500m
Min replicas:    1
Max replicas:    4
ReplicationController pods:  1 current / 1 desired
Conditions: 1
  Type          Status Reason          Message
  ----          -
  AbleToScale   True   ReadyForNewScale  the last scale time was sufficiently old as to warrant
a new scale
  ScalingActive True   ValidMetricFound  the HPA was able to successfully calculate a replica
count from pods metric http_request
  ScalingLimited False  DesiredWithinRange the desired replica count is within the acceptable
range
```

#### 2.4.9. Additional resources

- For more information on replication controllers and deployment controllers, see [Understanding deployments and deployment configs](#).
- For an example on the usage of HPA, see [Horizontal Pod Autoscaling of Quarkus Application Based on Memory Utilization](#).

## 2.5. AUTOMATICALLY ADJUST POD RESOURCE LEVELS WITH THE VERTICAL POD AUTOSCALER

The OpenShift Container Platform Vertical Pod Autoscaler Operator (VPA) automatically reviews the historic and current CPU and memory resources for containers in pods and can update the resource limits and requests based on the usage values it learns. The VPA uses individual custom resources (CR) to update all of the pods associated with a workload object, such as a **Deployment**, **DeploymentConfig**, **StatefulSet**, **Job**, **DaemonSet**, **ReplicaSet**, or **ReplicationController**, in a project.

The VPA helps you to understand the optimal CPU and memory usage for your pods and can automatically maintain pod resources through the pod lifecycle.

### 2.5.1. About the Vertical Pod Autoscaler Operator

The Vertical Pod Autoscaler Operator (VPA) is implemented as an API resource and a custom resource (CR). The CR determines the actions that the VPA Operator should take with the pods associated with a specific workload object, such as a daemon set, replication controller, and so forth, in a project.

The VPA Operator consists of three components, each of which has its own pod in the VPA namespace:

#### Recommender

The VPA recommender monitors the current and past resource consumption and, based on this data, determines the optimal CPU and memory resources for the pods in the associated workload object.

#### Updater

The VPA updater checks if the pods in the associated workload object have the correct resources. If the resources are correct, the updater takes no action. If the resources are not correct, the updater kills the pod so that they can be recreated by their controllers with the updated requests.

#### Admission controller

The VPA admission controller sets the correct resource requests on each new pod in the associated workload object, whether the pod is new or was recreated by its controller due to the VPA updater actions.

You can use the default recommender or use your own alternative recommender to autoscale based on your own algorithms.

The default recommender automatically computes historic and current CPU and memory usage for the containers in those pods and uses this data to determine optimized resource limits and requests to ensure that these pods are operating efficiently at all times. For example, the default recommender suggests reduced resources for pods that are requesting more resources than they are using and increased resources for pods that are not requesting enough.

The VPA then automatically deletes any pods that are out of alignment with these recommendations one at a time, so that your applications can continue to serve requests with no downtime. The workload objects then re-deploy the pods with the original resource limits and requests. The VPA uses a mutating admission webhook to update the pods with optimized resource limits and requests before the pods are admitted to a node. If you do not want the VPA to delete pods, you can view the VPA resource limits and requests and manually update the pods as needed.



#### NOTE

By default, workload objects must specify a minimum of two replicas in order for the VPA to automatically delete their pods. Workload objects that specify fewer replicas than this minimum are not deleted. If you manually delete these pods, when the workload object redeploys the pods, the VPA does update the new pods with its recommendations. You can change this minimum by modifying the **VerticalPodAutoscalerController** object as shown in *Changing the VPA minimum value*.

For example, if you have a pod that uses 50% of the CPU but only requests 10%, the VPA determines that the pod is consuming more CPU than requested and deletes the pod. The workload object, such as replica set, restarts the pods and the VPA updates the new pod with its recommended resources.

For developers, you can use the VPA to help ensure your pods stay up during periods of high demand by scheduling pods onto nodes that have appropriate resources for each pod.

Administrators can use the VPA to better utilize cluster resources, such as preventing pods from reserving more CPU resources than needed. The VPA monitors the resources that workloads are

actually using and adjusts the resource requirements so capacity is available to other workloads. The VPA also maintains the ratios between limits and requests that are specified in initial container configuration.



## NOTE

If you stop running the VPA or delete a specific VPA CR in your cluster, the resource requests for the pods already modified by the VPA do not change. Any new pods get the resources defined in the workload object, not the previous recommendations made by the VPA.

## 2.5.2. Installing the Vertical Pod Autoscaler Operator

You can use the OpenShift Container Platform web console to install the Vertical Pod Autoscaler Operator (VPA).

### Procedure

1. In the OpenShift Container Platform web console, click **Operators** → **OperatorHub**.
2. Choose **VerticalPodAutoscaler** from the list of available Operators, and click **Install**.
3. On the **Install Operator** page, ensure that the **Operator recommended namespace** option is selected. This installs the Operator in the mandatory **openshift-vertical-pod-autoscaler** namespace, which is automatically created if it does not exist.
4. Click **Install**.

### Verification

1. Verify the installation by listing the VPA Operator components:
  - a. Navigate to **Workloads** → **Pods**.
  - b. Select the **openshift-vertical-pod-autoscaler** project from the drop-down menu and verify that there are four pods running.
  - c. Navigate to **Workloads** → **Deployments** to verify that there are four deployments running.
2. Optional: Verify the installation in the OpenShift Container Platform CLI using the following command:

```
$ oc get all -n openshift-vertical-pod-autoscaler
```

The output shows four pods and four deployments:

### Example output

```
NAME                                READY STATUS RESTARTS AGE
pod/vertical-pod-autoscaler-operator-85b4569c47-2gmhc 1/1 Running 0      3m13s
pod/vpa-admission-plugin-default-67644fc87f-xq7k9    1/1 Running 0      2m56s
pod/vpa-recommender-default-7c54764b59-8gckt        1/1 Running 0      2m56s
pod/vpa-updater-default-7f6cc87858-47vw9           1/1 Running 0      2m56s

NAME          TYPE          CLUSTER-IP      EXTERNAL-IP  PORT(S)  AGE
```



```

service/vpa-webhook ClusterIP 172.30.53.206 <none> 443/TCP 2m56s

NAME                                READY  UP-TO-DATE  AVAILABLE  AGE
deployment.apps/vertical-pod-autoscaler-operator  1/1    1            1          3m13s
deployment.apps/vpa-admission-plugin-default      1/1    1            1          2m56s
deployment.apps/vpa-recommender-default          1/1    1            1          2m56s
deployment.apps/vpa-updater-default              1/1    1            1          2m56s

NAME                                DESIRED  CURRENT  READY  AGE
replicaset.apps/vertical-pod-autoscaler-operator-85b4569c47  1        1        1      3m13s
replicaset.apps/vpa-admission-plugin-default-67644fc87f      1        1        1      2m56s
replicaset.apps/vpa-recommender-default-7c54764b59           1        1        1      2m56s
replicaset.apps/vpa-updater-default-7f6cc87858              1        1        1      2m56s

```

### 2.5.3. Moving the Vertical Pod Autoscaler Operator components

The Vertical Pod Autoscaler Operator (VPA) and each component has its own pod in the VPA namespace on the control plane nodes. You can move the VPA Operator and component pods to infrastructure or worker nodes by adding a node selector to the VPA subscription and the **VerticalPodAutoscalerController** CR.

You can create and use infrastructure nodes to host only infrastructure components, such as the default router, the integrated container image registry, and the components for cluster metrics and monitoring. These infrastructure nodes are not counted toward the total number of subscriptions that are required to run the environment. For more information, see *Creating infrastructure machine sets*.

You can move the components to the same node or separate nodes as appropriate for your organization.

The following example shows the default deployment of the VPA pods to the control plane nodes.

#### Example output

```

NAME                                READY  STATUS  RESTARTS  AGE  IP             NODE
NOMINATED NODE  READINESS GATES
vertical-pod-autoscaler-operator-6c75fcc9cd-5pb6z  1/1    Running  0          7m59s  10.128.2.24
c416-tfsbj-master-1 <none>  <none>
vpa-admission-plugin-default-6cb78d6f8b-rpcrj      1/1    Running  0          5m37s  10.129.2.22
c416-tfsbj-master-1 <none>  <none>
vpa-recommender-default-66846bd94c-dsmpp           1/1    Running  0          5m37s  10.129.2.20
c416-tfsbj-master-0 <none>  <none>
vpa-updater-default-db8b58df-2nkvf                 1/1    Running  0          5m37s  10.129.2.21  c416-
tfsbj-master-1 <none>  <none>

```

#### Procedure

1. Move the VPA Operator pod by adding a node selector to the **Subscription** custom resource (CR) for the VPA Operator:

- a. Edit the CR:

```
$ oc edit Subscription vertical-pod-autoscaler -n openshift-vertical-pod-autoscaler
```

- b. Add a node selector to match the node role label on the node where you want to install the VPA Operator pod:

```

apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  labels:
    operators.coreos.com/vertical-pod-autoscaler.openshift-vertical-pod-autoscaler: ""
  name: vertical-pod-autoscaler
# ...
spec:
  config:
    nodeSelector:
      node-role.kubernetes.io/<node_role>: "" ❶

```

- ❶ Specifies the node role of the node where you want to move the VPA Operator pod.



## NOTE

If the infra node uses taints, you need to add a toleration to the **Subscription** CR.

For example:

```

apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  labels:
    operators.coreos.com/vertical-pod-autoscaler.openshift-vertical-pod-
autoscaler: ""
  name: vertical-pod-autoscaler
# ...
spec:
  config:
    nodeSelector:
      node-role.kubernetes.io/infra: ""
    tolerations: ❶
      - key: "node-role.kubernetes.io/infra"
        operator: "Exists"
        effect: "NoSchedule"

```

- ❶ Specifies a toleration for a taint on the node where you want to move the VPA Operator pod.

2. Move each VPA component by adding node selectors to the **VerticalPodAutoscaler** custom resource (CR):
  - a. Edit the CR:

```
$ oc edit VerticalPodAutoscalerController default -n openshift-vertical-pod-autoscaler
```

- b. Add node selectors to match the node role label on the node where you want to install the VPA components:

```
apiVersion: autoscaling.openshift.io/v1
```

```
kind: VerticalPodAutoscalerController
metadata:
  name: default
  namespace: openshift-vertical-pod-autoscaler
# ...
spec:
  deploymentOverrides:
    admission:
      container:
        resources: {}
        nodeSelector:
          node-role.kubernetes.io/<node_role>: "" 1
    recommender:
      container:
        resources: {}
        nodeSelector:
          node-role.kubernetes.io/<node_role>: "" 2
    updater:
      container:
        resources: {}
        nodeSelector:
          node-role.kubernetes.io/<node_role>: "" 3
```

- 1** Optional: Specifies the node role for the VPA admission pod.
- 2** Optional: Specifies the node role for the VPA recommender pod.
- 3** Optional: Specifies the node role for the VPA updater pod.



## NOTE

If a target node uses taints, you need to add a toleration to the **VerticalPodAutoscalerController** CR.

For example:

```

apiVersion: autoscaling.openshift.io/v1
kind: VerticalPodAutoscalerController
metadata:
  name: default
  namespace: openshift-vertical-pod-autoscaler
# ...
spec:
  deploymentOverrides:
    admission:
      container:
        resources: {}
        nodeSelector:
          node-role.kubernetes.io/worker: ""
        tolerations: 1
        - key: "my-example-node-taint-key"
          operator: "Exists"
          effect: "NoSchedule"
    recommender:
      container:
        resources: {}
        nodeSelector:
          node-role.kubernetes.io/worker: ""
        tolerations: 2
        - key: "my-example-node-taint-key"
          operator: "Exists"
          effect: "NoSchedule"
    updater:
      container:
        resources: {}
        nodeSelector:
          node-role.kubernetes.io/worker: ""
        tolerations: 3
        - key: "my-example-node-taint-key"
          operator: "Exists"
          effect: "NoSchedule"

```

- 1** Specifies a toleration for the admission controller pod for a taint on the node where you want to install the pod.
- 2** Specifies a toleration for the recommender pod for a taint on the node where you want to install the pod.
- 3** Specifies a toleration for the updater pod for a taint on the node where you want to install the pod.

## Verification

- You can verify the pods have moved by using the following command:

```
$ oc get pods -n openshift-vertical-pod-autoscaler -o wide
```

The pods are no longer deployed to the control plane nodes.

### Example output

```

NAME                                READY STATUS  RESTARTS  AGE  IP
NODE                                NOMINATED NODE  READINESS GATES
vertical-pod-autoscaler-operator-6c75fcc9cd-5pb6z  1/1  Running  0      7m59s
10.128.2.24  c416-tfsbj-infra-eastus3-2bndt  <none>      <none>
vpa-admission-plugin-default-6cb78d6f8b-rpcrj    1/1  Running  0      5m37s
10.129.2.22  c416-tfsbj-infra-eastus1-lrgj8  <none>      <none>
vpa-recommender-default-66846bd94c-dsmpp        1/1  Running  0      5m37s
10.129.2.20  c416-tfsbj-infra-eastus1-lrgj8  <none>      <none>
vpa-updater-default-db8b58df-2nkvf              1/1  Running  0      5m37s  10.129.2.21
c416-tfsbj-infra-eastus1-lrgj8  <none>      <none>

```

### Additional resources

- [Creating infrastructure machine sets](#)

## 2.5.4. About Using the Vertical Pod Autoscaler Operator

To use the Vertical Pod Autoscaler Operator (VPA), you create a VPA custom resource (CR) for a workload object in your cluster. The VPA learns and applies the optimal CPU and memory resources for the pods associated with that workload object. You can use a VPA with a deployment, stateful set, job, daemon set, replica set, or replication controller workload object. The VPA CR must be in the same project as the pods you want to monitor.

You use the VPA CR to associate a workload object and specify which mode the VPA operates in:

- The **Auto** and **Recreate** modes automatically apply the VPA CPU and memory recommendations throughout the pod lifetime. The VPA deletes any pods in the project that are out of alignment with its recommendations. When redeployed by the workload object, the VPA updates the new pods with its recommendations.
- The **Initial** mode automatically applies VPA recommendations only at pod creation.
- The **Off** mode only provides recommended resource limits and requests, allowing you to manually apply the recommendations. The **off** mode does not update pods.

You can also use the CR to opt-out certain containers from VPA evaluation and updates.

For example, a pod has the following limits and requests:

```

resources:
  limits:
    cpu: 1
    memory: 500Mi
  requests:
    cpu: 500m
    memory: 100Mi

```

After creating a VPA that is set to **auto**, the VPA learns the resource usage and deletes the pod. When redeployed, the pod uses the new resource limits and requests:

```
resources:
  limits:
    cpu: 50m
    memory: 1250Mi
  requests:
    cpu: 25m
    memory: 262144k
```

You can view the VPA recommendations using the following command:

```
$ oc get vpa <vpa-name> --output yaml
```

After a few minutes, the output shows the recommendations for CPU and memory requests, similar to the following:

### Example output

```
...
status:
...
recommendation:
  containerRecommendations:
  - containerName: frontend
    lowerBound:
      cpu: 25m
      memory: 262144k
    target:
      cpu: 25m
      memory: 262144k
    uncappedTarget:
      cpu: 25m
      memory: 262144k
    upperBound:
      cpu: 262m
      memory: "274357142"
  - containerName: backend
    lowerBound:
      cpu: 12m
      memory: 131072k
    target:
      cpu: 12m
      memory: 131072k
    uncappedTarget:
      cpu: 12m
      memory: 131072k
    upperBound:
      cpu: 476m
      memory: "498558823"
...
```

The output shows the recommended resources, **target**, the minimum recommended resources, **lowerBound**, the highest recommended resources, **upperBound**, and the most recent resource recommendations, **uncappedTarget**.

The VPA uses the **lowerBound** and **upperBound** values to determine if a pod needs to be updated. If a pod has resource requests below the **lowerBound** values or above the **upperBound** values, the VPA terminates and recreates the pod with the **target** values.

### 2.5.4.1. Changing the VPA minimum value

By default, workload objects must specify a minimum of two replicas in order for the VPA to automatically delete and update their pods. As a result, workload objects that specify fewer than two replicas are not automatically acted upon by the VPA. The VPA does update new pods from these workload objects if the pods are restarted by some process external to the VPA. You can change this cluster-wide minimum value by modifying the **minReplicas** parameter in the **VerticalPodAutoscalerController** custom resource (CR).

For example, if you set **minReplicas** to **3**, the VPA does not delete and update pods for workload objects that specify fewer than three replicas.



#### NOTE

If you set **minReplicas** to **1**, the VPA can delete the only pod for a workload object that specifies only one replica. You should use this setting with one-replica objects only if your workload can tolerate downtime whenever the VPA deletes a pod to adjust its resources. To avoid unwanted downtime with one-replica objects, configure the VPA CRs with the **podUpdatePolicy** set to **Initial**, which automatically updates the pod only when it is restarted by some process external to the VPA, or **Off**, which allows you to update the pod manually at an appropriate time for your application.

### Example VerticalPodAutoscalerController object

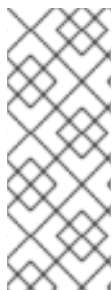
```
apiVersion: autoscaling.openshift.io/v1
kind: VerticalPodAutoscalerController
metadata:
  creationTimestamp: "2021-04-21T19:29:49Z"
  generation: 2
  name: default
  namespace: openshift-vertical-pod-autoscaler
  resourceVersion: "142172"
  uid: 180e17e9-03cc-427f-9955-3b4d7aeb2d59
spec:
  minReplicas: 3 1
  podMinCPUMillicores: 25
  podMinMemoryMb: 250
  recommendationOnly: false
  safetyMarginFraction: 0.15
```

- 1 Specify the minimum number of replicas in a workload object for the VPA to act on. Any objects with replicas fewer than the minimum are not automatically deleted by the VPA.

### 2.5.4.2. Automatically applying VPA recommendations

To use the VPA to automatically update pods, create a VPA CR for a specific workload object with **updateMode** set to **Auto** or **Recreate**.

When the pods are created for the workload object, the VPA constantly monitors the containers to analyze their CPU and memory needs. The VPA deletes any pods that do not meet the VPA recommendations for CPU and memory. When redeployed, the pods use the new resource limits and requests based on the VPA recommendations, honoring any pod disruption budget set for your applications. The recommendations are added to the **status** field of the VPA CR for reference.



## NOTE

By default, workload objects must specify a minimum of two replicas in order for the VPA to automatically delete their pods. Workload objects that specify fewer replicas than this minimum are not deleted. If you manually delete these pods, when the workload object redeployes the pods, the VPA does update the new pods with its recommendations. You can change this minimum by modifying the **VerticalPodAutoscalerController** object as shown in *Changing the VPA minimum value*.

## Example VPA CR for the Auto mode

```
apiVersion: autoscaling.k8s.io/v1
kind: VerticalPodAutoscaler
metadata:
  name: vpa-recommender
spec:
  targetRef:
    apiVersion: "apps/v1"
    kind: Deployment 1
    name: frontend 2
  updatePolicy:
    updateMode: "Auto" 3
```

- 1** The type of workload object you want this VPA CR to manage.
- 2** The name of the workload object you want this VPA CR to manage.
- 3** Set the mode to **Auto** or **Recreate**:
  - **Auto.** The VPA assigns resource requests on pod creation and updates the existing pods by terminating them when the requested resources differ significantly from the new recommendation.
  - **Recreate.** The VPA assigns resource requests on pod creation and updates the existing pods by terminating them when the requested resources differ significantly from the new recommendation. This mode should be used rarely, only if you need to ensure that the pods are restarted whenever the resource request changes.



**NOTE**

Before a VPA can determine recommendations for resources and apply the recommended resources to new pods, operating pods must exist and be running in the project.

If a workload's resource usage, such as CPU and memory, is consistent, the VPA can determine recommendations for resources in a few minutes. If a workload's resource usage is inconsistent, the VPA must collect metrics at various resource usage intervals for the VPA to make an accurate recommendation.

### 2.5.4.3. Automatically applying VPA recommendations on pod creation

To use the VPA to apply the recommended resources only when a pod is first deployed, create a VPA CR for a specific workload object with **updateMode** set to **Initial**.

Then, manually delete any pods associated with the workload object that you want to use the VPA recommendations. In the **Initial** mode, the VPA does not delete pods and does not update the pods as it learns new resource recommendations.

#### Example VPA CR for the Initial mode

```
apiVersion: autoscaling.k8s.io/v1
kind: VerticalPodAutoscaler
metadata:
  name: vpa-recommender
spec:
  targetRef:
    apiVersion: "apps/v1"
    kind: Deployment 1
    name: frontend 2
  updatePolicy:
    updateMode: "Initial" 3
```

- 1** The type of workload object you want this VPA CR to manage.
- 2** The name of the workload object you want this VPA CR to manage.
- 3** Set the mode to **Initial**. The VPA assigns resources when pods are created and does not change the resources during the lifetime of the pod.

**NOTE**

Before a VPA can determine recommended resources and apply the recommendations to new pods, operating pods must exist and be running in the project.

To obtain the most accurate recommendations from the VPA, wait at least 8 days for the pods to run and for the VPA to stabilize.

### 2.5.4.4. Manually applying VPA recommendations

To use the VPA to only determine the recommended CPU and memory values, create a VPA CR for a specific workload object with **updateMode** set to **off**.

When the pods are created for that workload object, the VPA analyzes the CPU and memory needs of the containers and records those recommendations in the **status** field of the VPA CR. The VPA does not update the pods as it determines new resource recommendations.

### Example VPA CR for the **Off** mode

```
apiVersion: autoscaling.k8s.io/v1
kind: VerticalPodAutoscaler
metadata:
  name: vpa-recommender
spec:
  targetRef:
    apiVersion: "apps/v1"
    kind: Deployment 1
    name: frontend 2
  updatePolicy:
    updateMode: "Off" 3
```

- 1** The type of workload object you want this VPA CR to manage.
- 2** The name of the workload object you want this VPA CR to manage.
- 3** Set the mode to **Off**.

You can view the recommendations using the following command.

```
$ oc get vpa <vpa-name> --output yaml
```

With the recommendations, you can edit the workload object to add CPU and memory requests, then delete and redeploy the pods using the recommended resources.



#### NOTE

Before a VPA can determine recommended resources and apply the recommendations to new pods, operating pods must exist and be running in the project.

To obtain the most accurate recommendations from the VPA, wait at least 8 days for the pods to run and for the VPA to stabilize.

#### 2.5.4.5. Exempting containers from applying VPA recommendations

If your workload object has multiple containers and you do not want the VPA to evaluate and act on all of the containers, create a VPA CR for a specific workload object and add a **resourcePolicy** to opt-out specific containers.

When the VPA updates the pods with recommended resources, any containers with a **resourcePolicy** are not updated and the VPA does not present recommendations for those containers in the pod.

```
apiVersion: autoscaling.k8s.io/v1
kind: VerticalPodAutoscaler
metadata:
  name: vpa-recommender
spec:
```

```
targetRef:
  apiVersion: "apps/v1"
  kind: Deployment 1
  name: frontend 2
updatePolicy:
  updateMode: "Auto" 3
resourcePolicy: 4
containerPolicies:
  - containerName: my-opt-sidecar
    mode: "Off"
```

- 1 The type of workload object you want this VPA CR to manage.
- 2 The name of the workload object you want this VPA CR to manage.
- 3 Set the mode to **Auto**, **Recreate**, or **Off**. The **Recreate** mode should be used rarely, only if you need to ensure that the pods are restarted whenever the resource request changes.
- 4 Specify the containers you want to opt-out and set **mode** to **Off**.

For example, a pod has two containers, the same resource requests and limits:

```
# ...
spec:
  containers:
  - name: frontend
    resources:
      limits:
        cpu: 1
        memory: 500Mi
      requests:
        cpu: 500m
        memory: 100Mi
  - name: backend
    resources:
      limits:
        cpu: "1"
        memory: 500Mi
      requests:
        cpu: 500m
        memory: 100Mi
# ...
```

After launching a VPA CR with the **backend** container set to opt-out, the VPA terminates and recreates the pod with the recommended resources applied only to the **frontend** container:

```
...
spec:
  containers:
  name: frontend
  resources:
    limits:
      cpu: 50m
      memory: 1250Mi
```

```

    requests:
      cpu: 25m
      memory: 262144k
    ...
  name: backend
  resources:
    limits:
      cpu: "1"
      memory: 500Mi
    requests:
      cpu: 500m
      memory: 100Mi
  ...

```

#### 2.5.4.6. Performance tuning the VPA Operator

As a cluster administrator, you can tune the performance of your Vertical Pod Autoscaler Operator (VPA) to limit the rate at which the VPA makes requests of the Kubernetes API server and to specify the CPU and memory resources for the VPA recommender, updater, and admission controller component pods.

Additionally, you can configure the VPA Operator to monitor only those workloads that are being managed by a VPA custom resource (CR). By default, the VPA Operator monitors every workload in the cluster. This allows the VPA Operator to accrue and store 8 days of historical data for all workloads, which the Operator can use if a new VPA CR is created for a workload. However, this causes the VPA Operator to use significant CPU and memory, which could cause the Operator to fail, particularly on larger clusters. By configuring the VPA Operator to monitor only workloads with a VPA CR, you can save on CPU and memory resources. One trade-off is that if you have a workload that has been running, and you create a VPA CR to manage that workload, the VPA Operator does not have any historical data for that workload. As a result, the initial recommendations are not as useful as those after the workload had been running for some time.

These tunings allow you to ensure the VPA has sufficient resources to operate at peak efficiency and to prevent throttling and a possible delay in pod admissions.

You can perform the following tunings on the VPA components by editing the **VerticalPodAutoscalerController** custom resource (CR):

- To prevent throttling and pod admission delays, set the queries-per-second (QPS) and burst rates for VPA requests of the Kubernetes API server by using the **kube-api-qps** and **kube-api-burst** parameters.
- To ensure sufficient CPU and memory, set the CPU and memory requests for VPA component pods by using the standard **cpu** and **memory** resource requests.
- To configure the VPA Operator to monitor only workloads that are being managed by a VPA CR, set the **memory-saver** parameter to **true** for the recommender component.

The following example VPA controller CR sets the VPA API QPS and burts rates, configures the component pod resource requests, and sets **memory-saver** to **true** for the recommender:

#### Example VerticalPodAutoscalerController CR

```

apiVersion: autoscaling.openshift.io/v1
kind: VerticalPodAutoscalerController
metadata:

```

```

name: default
namespace: openshift-vertical-pod-autoscaler
spec:
  deploymentOverrides:
    admission: ❶
    container:
      args: ❷
      - '--kube-api-qps=30.0'
      - '--kube-api-burst=40.0'
      resources:
        requests: ❸
        cpu: 40m
        memory: 40Mi
    recommender: ❹
    container:
      args:
      - '--kube-api-qps=20.0'
      - '--kube-api-burst=60.0'
      - '--memory-saver=true' ❺
      resources:
        requests:
        cpu: 60m
        memory: 60Mi
    updater: ❻
    container:
      args:
      - '--kube-api-qps=20.0'
      - '--kube-api-burst=80.0'
      resources:
        requests:
        cpu: 80m
        memory: 80Mi
  minReplicas: 2
  podMinCPUMillicores: 25
  podMinMemoryMb: 250
  recommendationOnly: false
  safetyMarginFraction: 0.15

```

- ❶ Specifies the tuning parameters for the VPA admission controller.
- ❷ Specifies the API QPS and burst rates for the VPA admission controller.
  - **kube-api-qps**: Specifies the queries per second (QPS) limit when making requests to Kubernetes API server. The default is **5.0**.
  - **kube-api-burst**: Specifies the burst limit when making requests to Kubernetes API server. The default is **10.0**.
- ❸ Specifies the CPU and memory requests for the VPA admission controller pod.
- ❹ Specifies the tuning parameters for the VPA recommender.
- ❺ Specifies that the VPA Operator monitors only workloads with a VPA CR. The default is **false**.
- ❻ Specifies the tuning parameters for the VPA updater.

You can verify that the settings were applied to each VPA component pod.

### Example updater pod

```
apiVersion: v1
kind: Pod
metadata:
  name: vpa-updater-default-d65ffb9dc-hgw44
  namespace: openshift-vertical-pod-autoscaler
# ...
spec:
  containers:
  - args:
    - --logtostderr
    - --v=1
    - --min-replicas=2
    - --kube-api-qps=20.0
    - --kube-api-burst=80.0
# ...
  resources:
    requests:
      cpu: 80m
      memory: 80Mi
# ...
```

### Example admission controller pod

```
apiVersion: v1
kind: Pod
metadata:
  name: vpa-admission-plugin-default-756999448c-l7tsd
  namespace: openshift-vertical-pod-autoscaler
# ...
spec:
  containers:
  - args:
    - --logtostderr
    - --v=1
    - --tls-cert-file=/data/tls-certs/tls.crt
    - --tls-private-key=/data/tls-certs/tls.key
    - --client-ca-file=/data/tls-ca-certs/service-ca.crt
    - --webhook-timeout-seconds=10
    - --kube-api-qps=30.0
    - --kube-api-burst=40.0
# ...
  resources:
    requests:
      cpu: 40m
      memory: 40Mi
# ...
```

### Example recommender pod

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

```

metadata:
  name: vpa-recommender-default-74c979dbbc-znrd2
  namespace: openshift-vertical-pod-autoscaler
# ...
spec:
  containers:
  - args:
    - --logtostderr
    - --v=1
    - --recommendation-margin-fraction=0.15
    - --pod-recommendation-min-cpu-millicores=25
    - --pod-recommendation-min-memory-mb=250
    - --kube-api-qps=20.0
    - --kube-api-burst=60.0
    - --memory-saver=true
# ...
resources:
  requests:
    cpu: 60m
    memory: 60Mi
# ...

```

#### 2.5.4.7. Using an alternative recommender

You can use your own recommender to autoscale based on your own algorithms. If you do not specify an alternative recommender, OpenShift Container Platform uses the default recommender, which suggests CPU and memory requests based on historical usage. Because there is no universal recommendation policy that applies to all types of workloads, you might want to create and deploy different recommenders for specific workloads.

For example, the default recommender might not accurately predict future resource usage when containers exhibit certain resource behaviors, such as cyclical patterns that alternate between usage spikes and idling as used by monitoring applications, or recurring and repeating patterns used with deep learning applications. Using the default recommender with these usage behaviors might result in significant over-provisioning and Out of Memory (OOM) kills for your applications.



#### NOTE

Instructions for how to create a recommender are beyond the scope of this documentation,

#### Procedure

To use an alternative recommender for your pods:

1. Create a service account for the alternative recommender and bind that service account to the required cluster role:

```

apiVersion: v1 1
kind: ServiceAccount
metadata:
  name: alt-vpa-recommender-sa
  namespace: <namespace_name>
---
apiVersion: rbac.authorization.k8s.io/v1 2

```

```

kind: ClusterRoleBinding
metadata:
  name: system:example-metrics-reader
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: system:metrics-reader
subjects:
- kind: ServiceAccount
  name: alt-vpa-recommender-sa
  namespace: <namespace_name>
---
apiVersion: rbac.authorization.k8s.io/v1 3
kind: ClusterRoleBinding
metadata:
  name: system:example-vpa-actor
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: system:vpa-actor
subjects:
- kind: ServiceAccount
  name: alt-vpa-recommender-sa
  namespace: <namespace_name>
---
apiVersion: rbac.authorization.k8s.io/v1 4
kind: ClusterRoleBinding
metadata:
  name: system:example-vpa-target-reader-binding
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: system:vpa-target-reader
subjects:
- kind: ServiceAccount
  name: alt-vpa-recommender-sa
  namespace: <namespace_name>

```

- 1 Creates a service account for the recommender in the namespace where the recommender is deployed.
- 2 Binds the recommender service account to the **metrics-reader** role. Specify the namespace where the recommender is to be deployed.
- 3 Binds the recommender service account to the **vpa-actor** role. Specify the namespace where the recommender is to be deployed.
- 4 Binds the recommender service account to the **vpa-target-reader** role. Specify the namespace where the recommender is to be deployed.

2. To add the alternative recommender to the cluster, create a Deployment object similar to the following:

```

apiVersion: apps/v1
kind: Deployment

```



```

metadata:
  name: alt-vpa-recommender
  namespace: <namespace_name>
spec:
  replicas: 1
  selector:
    matchLabels:
      app: alt-vpa-recommender
  template:
    metadata:
      labels:
        app: alt-vpa-recommender
    spec:
      containers: 1
      - name: recommender
        image: quay.io/example/alt-recommender:latest 2
        imagePullPolicy: Always
        resources:
          limits:
            cpu: 200m
            memory: 1000Mi
          requests:
            cpu: 50m
            memory: 500Mi
        ports:
          - name: prometheus
            containerPort: 8942
        securityContext:
          allowPrivilegeEscalation: false
          capabilities:
            drop:
              - ALL
          seccompProfile:
            type: RuntimeDefault
      serviceAccountName: alt-vpa-recommender-sa 3
      securityContext:
        runAsNonRoot: true

```

- 1** Creates a container for your alternative recommender.
- 2** Specifies your recommender image.
- 3** Associates the service account that you created for the recommender.

A new pod is created for the alternative recommender in the same namespace.

```
$ oc get pods
```

### Example output

```

NAME                                READY STATUS RESTARTS AGE
frontend-845d5478d-558zf            1/1   Running 0     4m25s
frontend-845d5478d-7z9gx            1/1   Running 0     4m25s

```

```
frontend-845d5478d-b7l4j          1/1   Running 0    4m25s
vpa-alt-recommender-55878867f9-6tp5v  1/1   Running 0    9s
```

- Configure a VPA CR that includes the name of the alternative recommender **Deployment** object.

### Example VPA CR to include the alternative recommender

```
apiVersion: autoscaling.k8s.io/v1
kind: VerticalPodAutoscaler
metadata:
  name: vpa-recommender
  namespace: <namespace_name>
spec:
  recommenders:
    - name: alt-vpa-recommender 1
  targetRef:
    apiVersion: "apps/v1"
    kind: Deployment 2
    name: frontend
```

- Specifies the name of the alternative recommender deployment.
- Specifies the name of an existing workload object you want this VPA to manage.

## 2.5.5. Using the Vertical Pod Autoscaler Operator

You can use the Vertical Pod Autoscaler Operator (VPA) by creating a VPA custom resource (CR). The CR indicates which pods it should analyze and determines the actions the VPA should take with those pods.

### Prerequisites

- The workload object that you want to autoscale must exist.
- If you want to use an alternative recommender, a deployment including that recommender must exist.

### Procedure

To create a VPA CR for a specific workload object:

- Change to the project where the workload object you want to scale is located.
  - Create a VPA CR YAML file:

```
apiVersion: autoscaling.k8s.io/v1
kind: VerticalPodAutoscaler
metadata:
  name: vpa-recommender
spec:
  targetRef:
    apiVersion: "apps/v1"
    kind: Deployment 1
```

```

name: frontend 2
updatePolicy:
  updateMode: "Auto" 3
resourcePolicy: 4
containerPolicies:
  - containerName: my-opt-sidecar
    mode: "Off"
recommenders: 5
  - name: my-recommender

```

- 1 Specify the type of workload object you want this VPA to manage: **Deployment**, **StatefulSet**, **Job**, **DaemonSet**, **ReplicaSet**, or **ReplicationController**.
- 2 Specify the name of an existing workload object you want this VPA to manage.
- 3 Specify the VPA mode:
  - **auto** to automatically apply the recommended resources on pods associated with the controller. The VPA terminates existing pods and creates new pods with the recommended resource limits and requests.
  - **recreate** to automatically apply the recommended resources on pods associated with the workload object. The VPA terminates existing pods and creates new pods with the recommended resource limits and requests. The **recreate** mode should be used rarely, only if you need to ensure that the pods are restarted whenever the resource request changes.
  - **initial** to automatically apply the recommended resources when pods associated with the workload object are created. The VPA does not update the pods as it learns new resource recommendations.
  - **off** to only generate resource recommendations for the pods associated with the workload object. The VPA does not update the pods as it learns new resource recommendations and does not apply the recommendations to new pods.
- 4 Optional. Specify the containers you want to opt-out and set the mode to **Off**.
- 5 Optional. Specify an alternative recommender.

b. Create the VPA CR:

```
$ oc create -f <file-name>.yaml
```

After a few moments, the VPA learns the resource usage of the containers in the pods associated with the workload object.

You can view the VPA recommendations using the following command:

```
$ oc get vpa <vpa-name> --output yaml
```

The output shows the recommendations for CPU and memory requests, similar to the following:

### Example output

-

```

...
status:
...

recommendation:
  containerRecommendations:
  - containerName: frontend
    lowerBound: ❶
      cpu: 25m
      memory: 262144k
    target: ❷
      cpu: 25m
      memory: 262144k
    uncappedTarget: ❸
      cpu: 25m
      memory: 262144k
    upperBound: ❹
      cpu: 262m
      memory: "274357142"
  - containerName: backend
    lowerBound:
      cpu: 12m
      memory: 131072k
    target:
      cpu: 12m
      memory: 131072k
    uncappedTarget:
      cpu: 12m
      memory: 131072k
    upperBound:
      cpu: 476m
      memory: "498558823"
...

```

- ❶ **lowerBound** is the minimum recommended resource levels.
- ❷ **target** is the recommended resource levels.
- ❸ **upperBound** is the highest recommended resource levels.
- ❹ **uncappedTarget** is the most recent resource recommendations.

## 2.5.6. Uninstalling the Vertical Pod Autoscaler Operator

You can remove the Vertical Pod Autoscaler Operator (VPA) from your OpenShift Container Platform cluster. After uninstalling, the resource requests for the pods already modified by an existing VPA CR do not change. Any new pods get the resources defined in the workload object, not the previous recommendations made by the Vertical Pod Autoscaler Operator.

**NOTE**


You can remove a specific VPA CR by using the **oc delete vpa <vpa-name>** command. The same actions apply for resource requests as uninstalling the vertical pod autoscaler.

After removing the VPA Operator, it is recommended that you remove the other components associated with the Operator to avoid potential issues.

**Prerequisites**

- The Vertical Pod Autoscaler Operator must be installed.

**Procedure**

1. In the OpenShift Container Platform web console, click **Operators** → **Installed Operators**.
2. Switch to the **openshift-vertical-pod-autoscaler** project.
3. For the **VerticalPodAutoscaler** Operator, click the Options menu  and select **Uninstall Operator**.
4. Optional: To remove all operands associated with the Operator, in the dialog box, select **Delete all operand instances for this operator** checkbox.
5. Click **Uninstall**.
6. Optional: Use the OpenShift CLI to remove the VPA components:

- a. Delete the VPA namespace:

```
$ oc delete namespace openshift-vertical-pod-autoscaler
```

- b. Delete the VPA custom resource definition (CRD) objects:

```
$ oc delete crd verticalpodautoscalercheckpoints.autoscaling.k8s.io
```

```
$ oc delete crd verticalpodautoscalercontrollers.autoscaling.openshift.io
```

```
$ oc delete crd verticalpodautoscalers.autoscaling.k8s.io
```

Deleting the CRDs removes the associated roles, cluster roles, and role bindings.

**NOTE**

This action removes from the cluster all user-created VPA CRs. If you re-install the VPA, you must create these objects again.

- c. Delete the **MutatingWebhookConfiguration** object by running the following command:

```
$ oc delete MutatingWebhookConfiguration vpa-webhook-config
```

d. Delete the VPA Operator:

```
$ oc delete operator/vertical-pod-autoscaler.openshift-vertical-pod-autoscaler
```

## 2.6. PROVIDING SENSITIVE DATA TO PODS BY USING SECRETS

Some applications need sensitive information, such as passwords and user names, that you do not want developers to have.

As an administrator, you can use **Secret** objects to provide this information without exposing that information in clear text.

### 2.6.1. Understanding secrets

The **Secret** object type provides a mechanism to hold sensitive information such as passwords, OpenShift Container Platform client configuration files, private source repository credentials, and so on. Secrets decouple sensitive content from the pods. You can mount secrets into containers using a volume plugin or the system can use secrets to perform actions on behalf of a pod.

Key properties include:

- Secret data can be referenced independently from its definition.
- Secret data volumes are backed by temporary file-storage facilities (tmpfs) and never come to rest on a node.
- Secret data can be shared within a namespace.

#### YAML Secret object definition

```
apiVersion: v1
kind: Secret
metadata:
  name: test-secret
  namespace: my-namespace
type: Opaque 1
data: 2
  username: <username> 3
  password: <password>
stringData: 4
  hostname: myapp.mydomain.com 5
```

- 1** Indicates the structure of the secret's key names and values.
- 2** The allowable format for the keys in the **data** field must meet the guidelines in the **DNS\_SUBDOMAIN** value in [the Kubernetes identifiers glossary](#).
- 3** The value associated with keys in the **data** map must be base64 encoded.
- 4** Entries in the **stringData** map are converted to base64 and the entry will then be moved to the **data** map automatically. This field is write-only; the value will only be returned via the **data** field.
- 5** The value associated with keys in the **stringData** map is made up of plain text strings.

You must create a secret before creating the pods that depend on that secret.

When creating secrets:

- Create a secret object with secret data.
- Update the pod's service account to allow the reference to the secret.
- Create a pod, which consumes the secret as an environment variable or as a file (using a **secret** volume).

### 2.6.1.1. Types of secrets

The value in the **type** field indicates the structure of the secret's key names and values. The type can be used to enforce the presence of user names and keys in the secret object. If you do not want validation, use the **opaque** type, which is the default.

Specify one of the following types to trigger minimal server-side validation to ensure the presence of specific key names in the secret data:

- **kubernetes.io/basic-auth**: Use with Basic authentication
- **kubernetes.io/dockercfg**: Use as an image pull secret
- **kubernetes.io/dockerconfigjson**: Use as an image pull secret
- **kubernetes.io/service-account-token**: Use to obtain a legacy service account API token
- **kubernetes.io/ssh-auth**: Use with SSH key authentication
- **kubernetes.io/tls**: Use with TLS certificate authorities

Specify **type: Opaque** if you do not want validation, which means the secret does not claim to conform to any convention for key names or values. An *opaque* secret, allows for unstructured **key:value** pairs that can contain arbitrary values.



#### NOTE

You can specify other arbitrary types, such as **example.com/my-secret-type**. These types are not enforced server-side, but indicate that the creator of the secret intended to conform to the key/value requirements of that type.

For examples of creating different types of secrets, see *Understanding how to create secrets*.

### 2.6.1.2. Secret data keys

Secret keys must be in a DNS subdomain.

### 2.6.1.3. Automatically generated image pull secrets

By default, OpenShift Container Platform creates an image pull secret for each service account.



## NOTE

Prior to OpenShift Container Platform 4.16, a long-lived service account API token secret was also generated for each service account that was created. Starting with OpenShift Container Platform 4.16, this service account API token secret is no longer created.

After upgrading to 4.17, any existing long-lived service account API token secrets are not deleted and will continue to function. For information about detecting long-lived API tokens that are in use in your cluster or deleting them if they are not needed, see the Red Hat Knowledgebase article [Long-lived service account API tokens in OpenShift Container Platform](#).

This image pull secret is necessary to integrate the OpenShift image registry into the cluster's user authentication and authorization system.

However, if you do not enable the **ImageRegistry** capability or if you disable the integrated OpenShift image registry in the Cluster Image Registry Operator's configuration, an image pull secret is not generated for each service account.

When the integrated OpenShift image registry is disabled on a cluster that previously had it enabled, the previously generated image pull secrets are deleted automatically.

## 2.6.2. Understanding how to create secrets

As an administrator you must create a secret before developers can create the pods that depend on that secret.

When creating secrets:

1. Create a secret object that contains the data you want to keep secret. The specific data required for each secret type is described in the following sections.

### Example YAML object that creates an opaque secret

```

apiVersion: v1
kind: Secret
metadata:
  name: test-secret
type: Opaque 1
data: 2
  username: <username>
  password: <password>
stringData: 3
  hostname: myapp.mydomain.com
secret.properties: |
  property1=valueA
  property2=valueB

```

- 1** Specifies the type of secret.
- 2** Specifies encoded string and data.
- 3** Specifies decoded string and data.



Use either the **data** or **stringdata** fields, not both.

- Update the pod's service account to reference the secret:

### YAML of a service account that uses a secret

```
apiVersion: v1
kind: ServiceAccount
...
secrets:
- name: test-secret
```

- Create a pod, which consumes the secret as an environment variable or as a file (using a **secret** volume):

### YAML of a pod populating files in a volume with secret data

```
apiVersion: v1
kind: Pod
metadata:
  name: secret-example-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: secret-test-container
    image: busybox
    command: [ "/bin/sh", "-c", "cat /etc/secret-volume/*" ]
    volumeMounts: 1
      - name: secret-volume
        mountPath: /etc/secret-volume 2
        readOnly: true 3
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
  volumes:
  - name: secret-volume
    secret:
      secretName: test-secret 4
  restartPolicy: Never
```

- Add a **volumeMounts** field to each container that needs the secret.
- Specifies an unused directory name where you would like the secret to appear. Each key in the secret data map becomes the filename under **mountPath**.
- Set to **true**. If true, this instructs the driver to provide a read-only volume.
- Specifies the name of the secret.

### YAML of a pod populating environment variables with secret data

```

apiVersion: v1
kind: Pod
metadata:
  name: secret-example-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: secret-test-container
    image: busybox
    command: [ "/bin/sh", "-c", "export" ]
    env:
    - name: TEST_SECRET_USERNAME_ENV_VAR
      valueFrom:
        secretKeyRef: ❶
          name: test-secret
          key: username
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
    restartPolicy: Never

```

❶ Specifies the environment variable that consumes the secret key.

### YAML of a build config populating environment variables with secret data

```

apiVersion: build.openshift.io/v1
kind: BuildConfig
metadata:
  name: secret-example-bc
spec:
  strategy:
    sourceStrategy:
      env:
      - name: TEST_SECRET_USERNAME_ENV_VAR
        valueFrom:
          secretKeyRef: ❶
            name: test-secret
            key: username
      from:
        kind: ImageStreamTag
        namespace: openshift
        name: 'cli:latest'

```

❶ Specifies the environment variable that consumes the secret key.

#### 2.6.2.1. Secret creation restrictions

To use a secret, a pod needs to reference the secret. A secret can be used with a pod in three ways:

- To populate environment variables for containers.
- As files in a volume mounted on one or more of its containers.
- By kubelet when pulling images for the pod.

Volume type secrets write data into the container as a file using the volume mechanism. Image pull secrets use service accounts for the automatic injection of the secret into all pods in a namespace.

When a template contains a secret definition, the only way for the template to use the provided secret is to ensure that the secret volume sources are validated and that the specified object reference actually points to a **Secret** object. Therefore, a secret needs to be created before any pods that depend on it. The most effective way to ensure this is to have it get injected automatically through the use of a service account.

Secret API objects reside in a namespace. They can only be referenced by pods in that same namespace.

Individual secrets are limited to 1MB in size. This is to discourage the creation of large secrets that could exhaust apiserver and kubelet memory. However, creation of a number of smaller secrets could also exhaust memory.

### 2.6.2.2. Creating an opaque secret

As an administrator, you can create an opaque secret, which allows you to store unstructured **key:value** pairs that can contain arbitrary values.

#### Procedure

1. Create a **Secret** object in a YAML file on a control plane node.  
For example:

```
apiVersion: v1
kind: Secret
metadata:
  name: mysecret
type: Opaque 1
data:
  username: <username>
  password: <password>
```

- 1** Specifies an opaque secret.

2. Use the following command to create a **Secret** object:

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

3. To use the secret in a pod:
  - a. Update the pod's service account to reference the secret, as shown in the "Understanding how to create secrets" section.
  - b. Create the pod, which consumes the secret as an environment variable or as a file (using a **secret** volume), as shown in the "Understanding how to create secrets" section.

## Additional resources

- [Understanding how to create secrets](#)

### 2.6.2.3. Creating a legacy service account token secret

As an administrator, you can create a legacy service account token secret, which allows you to distribute a service account token to applications that must authenticate to the API.



#### WARNING

It is recommended to obtain bound service account tokens using the TokenRequest API instead of using legacy service account token secrets. You should create a service account token secret only if you cannot use the TokenRequest API and if the security exposure of a nonexpiring token in a readable API object is acceptable to you.

Bound service account tokens are more secure than service account token secrets for the following reasons:

- Bound service account tokens have a bounded lifetime.
- Bound service account tokens contain audiences.
- Bound service account tokens can be bound to pods or secrets and the bound tokens are invalidated when the bound object is removed.

Workloads are automatically injected with a projected volume to obtain a bound service account token. If your workload needs an additional service account token, add an additional projected volume in your workload manifest.

For more information, see "Configuring bound service account tokens using volume projection".

## Procedure

1. Create a **Secret** object in a YAML file on a control plane node:

#### Example Secret object

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-sa-sample
annotations:
  kubernetes.io/service-account.name: "sa-name" 1
type: kubernetes.io/service-account-token 2
```

- 1** Specifies an existing service account name. If you are creating both the **ServiceAccount** and the **Secret** objects, create the **ServiceAccount** object first.

- 2. Specifies a service account token secret.

2. Use the following command to create the **Secret** object:

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

3. To use the secret in a pod:
  - a. Update the pod's service account to reference the secret, as shown in the "Understanding how to create secrets" section.
  - b. Create the pod, which consumes the secret as an environment variable or as a file (using a **secret** volume), as shown in the "Understanding how to create secrets" section.

### Additional resources

- [Understanding how to create secrets](#)
- [Configuring bound service account tokens using volume projection](#)
- [Understanding and creating service accounts](#)

#### 2.6.2.4. Creating a basic authentication secret

As an administrator, you can create a basic authentication secret, which allows you to store the credentials needed for basic authentication. When using this secret type, the **data** parameter of the **Secret** object must contain the following keys encoded in the base64 format:

- **username**: the user name for authentication
- **password**: the password or token for authentication



#### NOTE

You can use the **stringData** parameter to use clear text content.

### Procedure

1. Create a **Secret** object in a YAML file on a control plane node:

#### Example secret object

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-basic-auth
type: kubernetes.io/basic-auth 1
data:
stringData: 2
  username: admin
  password: <password>
```

- 1. Specifies a basic authentication secret.

- 2 Specifies the basic authentication values to use.

2. Use the following command to create the **Secret** object:

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

3. To use the secret in a pod:

- a. Update the pod's service account to reference the secret, as shown in the "Understanding how to create secrets" section.
- b. Create the pod, which consumes the secret as an environment variable or as a file (using a **secret** volume), as shown in the "Understanding how to create secrets" section.

### Additional resources

- [Understanding how to create secrets](#)

### 2.6.2.5. Creating an SSH authentication secret

As an administrator, you can create an SSH authentication secret, which allows you to store data used for SSH authentication. When using this secret type, the **data** parameter of the **Secret** object must contain the SSH credential to use.

#### Procedure

1. Create a **Secret** object in a YAML file on a control plane node:

#### Example secret object

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-ssh-auth
type: kubernetes.io/ssh-auth 1
data:
  ssh-privatekey: | 2
    MIIEpQIBAAKCAQEAlqb/Y ...
```

- 1 Specifies an SSH authentication secret.
- 2 Specifies the SSH key/value pair as the SSH credentials to use.

2. Use the following command to create the **Secret** object:

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

3. To use the secret in a pod:

- a. Update the pod's service account to reference the secret, as shown in the "Understanding how to create secrets" section.

- b. Create the pod, which consumes the secret as an environment variable or as a file (using a **secret** volume), as shown in the "Understanding how to create secrets" section.

### Additional resources

- [Understanding how to create secrets](#)

### 2.6.2.6. Creating a Docker configuration secret

As an administrator, you can create a Docker configuration secret, which allows you to store the credentials for accessing a container image registry.

- **kubernetes.io/dockercfg**. Use this secret type to store your local Docker configuration file. The **data** parameter of the **secret** object must contain the contents of a **.dockercfg** file encoded in the base64 format.
- **kubernetes.io/dockerconfigjson**. Use this secret type to store your local Docker configuration JSON file. The **data** parameter of the **secret** object must contain the contents of a **.docker/config.json** file encoded in the base64 format.

### Procedure

1. Create a **Secret** object in a YAML file on a control plane node.

#### Example Docker configuration secret object

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-docker-cfg
  namespace: my-project
type: kubernetes.io/dockerconfig 1
data:
  .dockerconfig:bm5ubm5ubm5ubm5ubm5ubm5ubmdnZ2dnZ2dnZ2dnZ2dnZ2dnZ2cgYXV
  0aCBrZXlzcG== 2
```

**1** Specifies that the secret is using a Docker configuration file.

**2** The output of a base64-encoded Docker configuration file

#### Example Docker configuration JSON secret object

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-docker-json
  namespace: my-project
type: kubernetes.io/dockerconfig 1
data:
  .dockerconfigjson:bm5ubm5ubm5ubm5ubm5ubm5ubmdnZ2dnZ2dnZ2dnZ2dnZ2cg
  YXV0aCBrZXlzcG== 2
```

- 1 Specifies that the secret is using a Docker configuration JSONfile.
- 2 The output of a base64-encoded Docker configuration JSON file

2. Use the following command to create the **Secret** object

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

3. To use the secret in a pod:

- a. Update the pod's service account to reference the secret, as shown in the "Understanding how to create secrets" section.
- b. Create the pod, which consumes the secret as an environment variable or as a file (using a **secret** volume), as shown in the "Understanding how to create secrets" section.

### Additional resources

- [Understanding how to create secrets](#)

### 2.6.2.7. Creating a secret using the web console

You can create secrets using the web console.

#### Procedure

1. Navigate to **Workloads** → **Secrets**.
2. Click **Create** → **From YAML**.
  - a. Edit the YAML manually to your specifications, or drag and drop a file into the YAML editor. For example:

```
apiVersion: v1
kind: Secret
metadata:
  name: example
  namespace: <namespace>
type: Opaque 1
data:
  username: <base64 encoded username>
  password: <base64 encoded password>
stringData: 2
  hostname: myapp.mydomain.com
```

- 1 This example specifies an opaque secret; however, you may see other secret types such as service account token secret, basic authentication secret, SSH authentication secret, or a secret that uses Docker configuration.
- 2 Entries in the **stringData** map are converted to base64 and the entry will then be moved to the **data** map automatically. This field is write-only; the value will only be returned via the **data** field.



3. Click **Create**.
4. Click **Add Secret to workload**
  - a. From the drop-down menu, select the workload to add.
  - b. Click **Save**.

### 2.6.3. Understanding how to update secrets

When you modify the value of a secret, the value (used by an already running pod) will not dynamically change. To change a secret, you must delete the original pod and create a new pod (perhaps with an identical PodSpec).

Updating a secret follows the same workflow as deploying a new Container image. You can use the **kubectrl rolling-update** command.

The **resourceVersion** value in a secret is not specified when it is referenced. Therefore, if a secret is updated at the same time as pods are starting, the version of the secret that is used for the pod is not defined.



#### NOTE

Currently, it is not possible to check the resource version of a secret object that was used when a pod was created. It is planned that pods will report this information, so that a controller could restart ones using an old **resourceVersion**. In the interim, do not update the data of existing secrets, but create new ones with distinct names.

### 2.6.4. Creating and using secrets

As an administrator, you can create a service account token secret. This allows you to distribute a service account token to applications that must authenticate to the API.

#### Procedure

1. Create a service account in your namespace by running the following command:

```
$ oc create sa <service_account_name> -n <your_namespace>
```

2. Save the following YAML example to a file named **service-account-token-secret.yaml**. The example includes a **Secret** object configuration that you can use to generate a service account token:

```
apiVersion: v1
kind: Secret
metadata:
  name: <secret_name> 1
  annotations:
    kubernetes.io/service-account.name: "sa-name" 2
type: kubernetes.io/service-account-token 3
```

- 1 Replace **<secret\_name>** with the name of your service token secret.
- 2 Specifies an existing service account name. If you are creating both the **ServiceAccount** and the **Secret** objects, create the **ServiceAccount** object first.



```
name: registry
annotations:
  service.beta.openshift.io/serving-cert-secret-name: registry-cert 1
# ...
```

- 1 Specify the name for the certificate

Other pods can trust cluster-created certificates (which are only signed for internal DNS names), by using the CA bundle in the `/var/run/secrets/kubernetes.io/serviceaccount/service-ca.crt` file that is automatically mounted in their pod.

The signature algorithm for this feature is **x509.SHA256WithRSA**. To manually rotate, delete the generated secret. A new certificate is created.

### 2.6.5.1. Generating signed certificates for use with secrets

To use a signed serving certificate/key pair with a pod, create or edit the service to add the **service.beta.openshift.io/serving-cert-secret-name** annotation, then add the secret to the pod.

#### Procedure

To create a *service serving certificate secret*:

1. Edit the **Pod** spec for your service.
2. Add the **service.beta.openshift.io/serving-cert-secret-name** annotation with the name you want to use for your secret.

```
kind: Service
apiVersion: v1
metadata:
  name: my-service
  annotations:
    service.beta.openshift.io/serving-cert-secret-name: my-cert 1
spec:
  selector:
    app: MyApp
  ports:
    - protocol: TCP
      port: 80
      targetPort: 9376
```

The certificate and key are in PEM format, stored in **tls.crt** and **tls.key** respectively.

3. Create the service:

```
$ oc create -f <file-name>.yaml
```

4. View the secret to make sure it was created:

- a. View a list of all secrets:

```
$ oc get secrets
```

**Example output**

NAME	TYPE	DATA	AGE
my-cert	kubernetes.io/tls	2	9m

- b. View details on your secret:

```
$ oc describe secret my-cert
```

**Example output**

```
Name:      my-cert
Namespace: openshift-console
Labels:    <none>
Annotations: service.beta.openshift.io/expiry: 2023-03-08T23:22:40Z
             service.beta.openshift.io/originating-service-name: my-service
             service.beta.openshift.io/originating-service-uid: 640f0ec3-afc2-4380-bf31-
             a8c784846a11
             service.beta.openshift.io/expiry: 2023-03-08T23:22:40Z

Type: kubernetes.io/tls

Data
====
tls.key: 1679 bytes
tls.crt: 2595 bytes
```

5. Edit your **Pod** spec with that secret.

```
apiVersion: v1
kind: Pod
metadata:
  name: my-service-pod
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - name: mypod
    image: redis
    volumeMounts:
    - name: my-container
      mountPath: "/etc/my-path"
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
  volumes:
  - name: my-volume
    secret:
      secretName: my-cert
    items:
```

```
- key: username
  path: my-group/my-username
  mode: 511
```

When it is available, your pod will run. The certificate will be good for the internal service DNS name, **<service.name>.<service.namespace>.svc**.

The certificate/key pair is automatically replaced when it gets close to expiration. View the expiration date in the **service.beta.openshift.io/expiry** annotation on the secret, which is in RFC3339 format.



## NOTE

In most cases, the service DNS name **<service.name>.<service.namespace>.svc** is not externally routable. The primary use of **<service.name>.<service.namespace>.svc** is for intracluster or intraservice communication, and with re-encrypt routes.

## 2.6.6. Troubleshooting secrets

If a service certificate generation fails with (service's **service.beta.openshift.io/serving-cert-generation-error** annotation contains):

```
secret/ssl-key references serviceUID 62ad25ca-d703-11e6-9d6f-0e9c0057b608, which does not
match 77b6dd80-d716-11e6-9d6f-0e9c0057b60
```

The service that generated the certificate no longer exists, or has a different **serviceUID**. You must force certificates regeneration by removing the old secret, and clearing the following annotations on the service **service.beta.openshift.io/serving-cert-generation-error**, **service.beta.openshift.io/serving-cert-generation-error-num**:

1. Delete the secret:

```
$ oc delete secret <secret_name>
```

2. Clear the annotations:

```
$ oc annotate service <service_name> service.beta.openshift.io/serving-cert-generation-
error-
```

```
$ oc annotate service <service_name> service.beta.openshift.io/serving-cert-generation-
error-num-
```



## NOTE

The command removing annotation has a - after the annotation name to be removed.

## 2.7. PROVIDING SENSITIVE DATA TO PODS BY USING AN EXTERNAL SECRETS STORE

Some applications need sensitive information, such as passwords and user names, that you do not want developers to have.

As an alternative to using Kubernetes **Secret** objects to provide sensitive information, you can use an external secrets store to store the sensitive information. You can use the Secrets Store CSI Driver Operator to integrate with an external secrets store and mount the secret content as a pod volume.



## IMPORTANT

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

For more information about the support scope of Red Hat Technology Preview features, see [Technology Preview Features Support Scope](#).

### 2.7.1. About the Secrets Store CSI Driver Operator

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.

#### 2.7.1.1. Secrets store providers

The following secrets store providers are available for use with the Secrets Store CSI Driver Operator:

- AWS Secrets Manager
- AWS Systems Manager Parameter Store
- Azure Key Vault
- HashiCorp Vault

#### 2.7.1.2. Automatic rotation

The Secrets Store CSI driver periodically rotates the content in the mounted volume with the content from the external secrets store. If a secret is updated in the external secrets store, the secret will be updated in the mounted volume. The Secrets Store CSI Driver Operator polls for updates every 2 minutes.

If you enabled synchronization of mounted content as Kubernetes secrets, the Kubernetes secrets are also rotated.

Applications consuming the secret data must watch for updates to the secrets.

## 2.7.2. 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**.

## 2.7.3. Mounting secrets from an external secrets store to a CSI volume

After installing the Secrets Store CSI Driver Operator, you can mount secrets from one of the following external secrets stores to a CSI volume:

- [AWS Secrets Manager](#)
- [AWS Systems Manager Parameter Store](#)
- [Azure Key Vault](#)
- [HashiCorp Vault](#)

### 2.7.3.1. Mounting secrets from AWS Secrets Manager

You can use the Secrets Store CSI Driver Operator to mount secrets from AWS Secrets Manager to a CSI volume in OpenShift Container Platform. To mount secrets from AWS Secrets Manager, your cluster must be installed on AWS and use AWS Security Token Service (STS).

#### Prerequisites

- Your cluster is installed on AWS and uses AWS Security Token Service (STS).
- You have installed the Secrets Store CSI Driver Operator. See *Installing the Secrets Store CSI driver* for instructions.
- You have configured AWS Secrets Manager to store the required secrets.
- You have extracted and prepared the **ccoctl** binary.
- You have installed the **jq** CLI tool.
- You have access to the cluster as a user with the **cluster-admin** role.

#### Procedure

1. Install the AWS Secrets Manager provider:
  - a. Create a YAML file with the following configuration for the provider resources:



#### IMPORTANT

The AWS Secrets Manager provider for the Secrets Store CSI driver is an upstream provider.

This configuration is modified from the configuration provided in the upstream [AWS documentation](#) so that it works properly with OpenShift Container Platform. Changes to this configuration might impact functionality.

#### Example `aws-provider.yaml` file

```
apiVersion: v1
kind: ServiceAccount
metadata:
  name: csi-secrets-store-provider-aws
  namespace: openshift-cluster-csi-drivers
---
```



```

apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRole
metadata:
  name: csi-secrets-store-provider-aws-cluster-role
rules:
- apiGroups: ["" ]
  resources: ["serviceaccounts/token"]
  verbs: ["create"]
- apiGroups: ["" ]
  resources: ["serviceaccounts"]
  verbs: ["get"]
- apiGroups: ["" ]
  resources: ["pods"]
  verbs: ["get"]
- apiGroups: ["" ]
  resources: ["nodes"]
  verbs: ["get"]
---
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRoleBinding
metadata:
  name: csi-secrets-store-provider-aws-cluster-rolebinding
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: csi-secrets-store-provider-aws-cluster-role
subjects:
- kind: ServiceAccount
  name: csi-secrets-store-provider-aws
  namespace: openshift-cluster-csi-drivers
---
apiVersion: apps/v1
kind: DaemonSet
metadata:
  namespace: openshift-cluster-csi-drivers
  name: csi-secrets-store-provider-aws
  labels:
    app: csi-secrets-store-provider-aws
spec:
  updateStrategy:
    type: RollingUpdate
  selector:
    matchLabels:
      app: csi-secrets-store-provider-aws
  template:
    metadata:
      labels:
        app: csi-secrets-store-provider-aws
    spec:
      serviceAccountName: csi-secrets-store-provider-aws
      hostNetwork: false
      containers:
        - name: provider-aws-installer
          image: public.ecr.aws/aws-secrets-manager/secrets-store-csi-driver-provider-aws:1.0.r2-50-g5b4aca1-2023.06.09.21.19
          imagePullPolicy: Always

```

```

args:
  - --provider-volume=/etc/kubernetes/secrets-store-csi-providers
resources:
  requests:
    cpu: 50m
    memory: 100Mi
  limits:
    cpu: 50m
    memory: 100Mi
securityContext:
  privileged: true
volumeMounts:
  - mountPath: "/etc/kubernetes/secrets-store-csi-providers"
    name: providervol
  - name: mountpoint-dir
    mountPath: /var/lib/kubelet/pods
    mountPropagation: HostToContainer
tolerations:
  - operator: Exists
volumes:
  - name: providervol
    hostPath:
      path: "/etc/kubernetes/secrets-store-csi-providers"
  - name: mountpoint-dir
    hostPath:
      path: /var/lib/kubelet/pods
      type: DirectoryOrCreate
nodeSelector:
  kubernetes.io/os: linux

```

- b. Grant privileged access to the **csi-secrets-store-provider-aws** service account by running the following command:

```
$ oc adm policy add-scc-to-user privileged -z csi-secrets-store-provider-aws -n openshift-cluster-csi-drivers
```

- c. Create the provider resources by running the following command:

```
$ oc apply -f aws-provider.yaml
```

2. Grant permission to allow the service account to read the AWS secret object:

- a. Create a directory to contain the credentials request by running the following command:

```
$ mkdir credentialsrequest-dir-aws
```

- b. Create a YAML file with the following configuration for the credentials request:

#### Example `credentialsrequest.yaml` file

```

apiVersion: cloudcredential.openshift.io/v1
kind: CredentialsRequest
metadata:
  name: aws-provider-test

```

```

namespace: openshift-cloud-credential-operator
spec:
  providerSpec:
    apiVersion: cloudcredential.openshift.io/v1
    kind: AWSProviderSpec
    statementEntries:
      - action:
          - "secretsmanager:GetSecretValue"
          - "secretsmanager:DescribeSecret"
        effect: Allow
        resource: "arn:*:secretsmanager:*:*:secret:testSecret-??????"
    secretRef:
      name: aws-creds
      namespace: my-namespace
    serviceAccountNames:
      - aws-provider

```

- c. Retrieve the OIDC provider by running the following command:

```
$ oc get --raw=/well-known/openid-configuration | jq -r '.issuer'
```

#### Example output

```
https://<oidc_provider_name>
```

Copy the OIDC provider name **<oidc\_provider\_name>** from the output to use in the next step.

- d. Use the **ccoctl** tool to process the credentials request by running the following command:

```
$ ccoctl aws create-iam-roles \
  --name my-role --region=<aws_region> \
  --credentials-requests-dir=credentialsrequest-dir-aws \
  --identity-provider-arn arn:aws:iam::<aws_account>:oidc-
provider/<oidc_provider_name> --output-dir=credrequests-ccoctl-output
```

#### Example output

```

2023/05/15 18:10:34 Role arn:aws:iam::<aws_account_id>:role/my-role-my-namespace-
aws-creds created
2023/05/15 18:10:34 Saved credentials configuration to: credrequests-ccoctl-
output/manifests/my-namespace-aws-creds-credentials.yaml
2023/05/15 18:10:35 Updated Role policy for Role my-role-my-namespace-aws-creds

```

Copy the **<aws\_role\_arn>** from the output to use in the next step. For example, **arn:aws:iam::<aws\_account\_id>:role/my-role-my-namespace-aws-creds**.

- e. Bind the service account with the role ARN by running the following command:

```
$ oc annotate -n my-namespace sa/aws-provider eks.amazonaws.com/role-arn="
<aws_role_arn>"
```

3. Create a secret provider class to define your secrets store provider:

- a. Create a YAML file that defines the **SecretProviderClass** object:

#### Example secret-provider-class-aws.yaml

```
apiVersion: secrets-store.csi.x-k8s.io/v1
kind: SecretProviderClass
metadata:
  name: my-aws-provider
  namespace: my-namespace
spec:
  provider: aws
  parameters:
    objects: |
      - objectName: "testSecret"
        objectType: "secretsmanager"
```

- 1 1 Specify the name for the secret provider class.
- 2 Specify the namespace for the secret provider class.
- 3 Specify the provider as **aws**.
- 4 Specify the provider-specific configuration parameters.

- b. Create the **SecretProviderClass** object by running the following command:

```
$ oc create -f secret-provider-class-aws.yaml
```

4. Create a deployment to use this secret provider class:

- a. Create a YAML file that defines the **Deployment** object:

#### Example deployment.yaml

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: my-aws-deployment
  namespace: my-namespace
spec:
  replicas: 1
  selector:
    matchLabels:
      app: my-storage
  template:
    metadata:
      labels:
        app: my-storage
    spec:
      serviceAccountName: aws-provider
      containers:
        - name: busybox
          image: k8s.gcr.io/e2e-test-images/busybox:1.29
```

```

command:
  - "/bin/sleep"
  - "10000"
volumeMounts:
  - name: secrets-store-inline
    mountPath: "/mnt/secrets-store"
    readOnly: true
volumes:
  - name: secrets-store-inline
    csi:
      driver: secrets-store.csi.k8s.io
      readOnly: true
      volumeAttributes:
        secretProviderClass: "my-aws-provider" 3

```

- 1 Specify the name for the deployment.
- 2 Specify the namespace for the deployment. This must be the same namespace as the secret provider class.
- 3 Specify the name of the secret provider class.

b. Create the **Deployment** object by running the following command:

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

### Verification

- Verify that you can access the secrets from AWS Secrets Manager in the pod volume mount:
  - a. List the secrets in the pod mount:

```
$ oc exec busybox-<hash> -n my-namespace -- ls /mnt/secrets-store/
```

#### Example output

```
testSecret
```

b. View a secret in the pod mount:

```
$ oc exec busybox-<hash> -n my-namespace -- cat /mnt/secrets-store/testSecret
```

#### Example output

```
<secret_value>
```

### Additional resources

- [Configuring the Cloud Credential Operator utility](#)

### 2.7.3.2. Mounting secrets from AWS Systems Manager Parameter Store

You can use the Secrets Store CSI Driver Operator to mount secrets from AWS Systems Manager Parameter Store to a CSI volume in OpenShift Container Platform. To mount secrets from AWS Systems Manager Parameter Store, your cluster must be installed on AWS and use AWS Security Token Service (STS).

## Prerequisites

- Your cluster is installed on AWS and uses AWS Security Token Service (STS).
- You have installed the Secrets Store CSI Driver Operator. See *Installing the Secrets Store CSI driver* for instructions.
- You have configured AWS Systems Manager Parameter Store to store the required secrets.
- You have extracted and prepared the **ccoctl** binary.
- You have installed the **jq** CLI tool.
- You have access to the cluster as a user with the **cluster-admin** role.

## Procedure

1. Install the AWS Systems Manager Parameter Store provider:
  - a. Create a YAML file with the following configuration for the provider resources:



### IMPORTANT

The AWS Systems Manager Parameter Store provider for the Secrets Store CSI driver is an upstream provider.

This configuration is modified from the configuration provided in the upstream [AWS documentation](#) so that it works properly with OpenShift Container Platform. Changes to this configuration might impact functionality.

### Example `aws-provider.yaml` file

```
apiVersion: v1
kind: ServiceAccount
metadata:
  name: csi-secrets-store-provider-aws
  namespace: openshift-cluster-csi-drivers
---
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRole
metadata:
  name: csi-secrets-store-provider-aws-cluster-role
rules:
- apiGroups: [""]
  resources: ["serviceaccounts/token"]
  verbs: ["create"]
- apiGroups: [""]
  resources: ["serviceaccounts"]
  verbs: ["get"]
- apiGroups: [""]
```

```

resources: ["pods"]
verbs: ["get"]
- apiGroups: [""]
  resources: ["nodes"]
  verbs: ["get"]
---
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRoleBinding
metadata:
  name: csi-secrets-store-provider-aws-cluster-rolebinding
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: csi-secrets-store-provider-aws-cluster-role
subjects:
- kind: ServiceAccount
  name: csi-secrets-store-provider-aws
  namespace: openshift-cluster-csi-drivers
---
apiVersion: apps/v1
kind: DaemonSet
metadata:
  namespace: openshift-cluster-csi-drivers
  name: csi-secrets-store-provider-aws
  labels:
    app: csi-secrets-store-provider-aws
spec:
  updateStrategy:
    type: RollingUpdate
  selector:
    matchLabels:
      app: csi-secrets-store-provider-aws
  template:
    metadata:
      labels:
        app: csi-secrets-store-provider-aws
    spec:
      serviceAccountName: csi-secrets-store-provider-aws
      hostNetwork: false
      containers:
        - name: provider-aws-installer
          image: public.ecr.aws/aws-secrets-manager/secrets-store-csi-driver-provider-aws:1.0.r2-50-g5b4aca1-2023.06.09.21.19
          imagePullPolicy: Always
          args:
            - --provider-volume=/etc/kubernetes/secrets-store-csi-providers
      resources:
        requests:
          cpu: 50m
          memory: 100Mi
        limits:
          cpu: 50m
          memory: 100Mi
      securityContext:
        privileged: true
      volumeMounts:

```

```

- mountPath: "/etc/kubernetes/secrets-store-csi-providers"
  name: providervol
- name: mountpoint-dir
  mountPath: /var/lib/kubelet/pods
  mountPropagation: HostToContainer
tolerations:
- operator: Exists
volumes:
- name: providervol
  hostPath:
    path: "/etc/kubernetes/secrets-store-csi-providers"
- name: mountpoint-dir
  hostPath:
    path: /var/lib/kubelet/pods
    type: DirectoryOrCreate
nodeSelector:
  kubernetes.io/os: linux

```

- b. Grant privileged access to the **csi-secrets-store-provider-aws** service account by running the following command:

```
$ oc adm policy add-scc-to-user privileged -z csi-secrets-store-provider-aws -n openshift-cluster-csi-drivers
```

- c. Create the provider resources by running the following command:

```
$ oc apply -f aws-provider.yaml
```

2. Grant permission to allow the service account to read the AWS secret object:

- a. Create a directory to contain the credentials request by running the following command:

```
$ mkdir credentialsrequest-dir-aws
```

- b. Create a YAML file with the following configuration for the credentials request:

#### Example `credentialsrequest.yaml` file

```

apiVersion: cloudcredential.openshift.io/v1
kind: CredentialsRequest
metadata:
  name: aws-provider-test
  namespace: openshift-cloud-credential-operator
spec:
  providerSpec:
    apiVersion: cloudcredential.openshift.io/v1
    kind: AWSProviderSpec
    statementEntries:
    - action:
      - "ssm:GetParameter"
      - "ssm:GetParameters"
      effect: Allow
      resource: "arn:*:ssm:*:*:parameter/testParameter*"
  secretRef:

```



```

name: aws-creds
namespace: my-namespace
serviceAccountNames:
- aws-provider

```

- c. Retrieve the OIDC provider by running the following command:

```
$ oc get --raw=/.well-known/openid-configuration | jq -r '.issuer'
```

### Example output

```
https://<oidc_provider_name>
```

Copy the OIDC provider name **<oidc\_provider\_name>** from the output to use in the next step.

- d. Use the **ccoctl** tool to process the credentials request by running the following command:

```

$ ccoctl aws create-iam-roles \
  --name my-role --region=<aws_region> \
  --credentials-requests-dir=credentialsrequest-dir-aws \
  --identity-provider-arn arn:aws:iam::<aws_account>:oidc-
  provider/<oidc_provider_name> --output-dir=credrequests-ccoctl-output

```

### Example output

```

2023/05/15 18:10:34 Role arn:aws:iam::<aws_account_id>:role/my-role-my-namespace-
aws-creds created
2023/05/15 18:10:34 Saved credentials configuration to: credrequests-ccoctl-
output/manifests/my-namespace-aws-creds-credentials.yaml
2023/05/15 18:10:35 Updated Role policy for Role my-role-my-namespace-aws-creds

```

Copy the **<aws\_role\_arn>** from the output to use in the next step. For example, **arn:aws:iam::<aws\_account\_id>:role/my-role-my-namespace-aws-creds**.

- e. Bind the service account with the role ARN by running the following command:

```
$ oc annotate -n my-namespace sa/aws-provider eks.amazonaws.com/role-arn="
<aws_role_arn>"
```

3. Create a secret provider class to define your secrets store provider:

- a. Create a YAML file that defines the **SecretProviderClass** object:

### Example secret-provider-class-aws.yaml

```

apiVersion: secrets-store.csi.x-k8s.io/v1
kind: SecretProviderClass
metadata:
  name: my-aws-provider
  namespace: my-namespace
spec:
  provider: aws

```

```
parameters:
  objects: |
    - objectName: "testParameter"
      objectType: "ssmparameter"
  4
```

- 1 Specify the name for the secret provider class.
- 2 Specify the namespace for the secret provider class.
- 3 Specify the provider as **aws**.
- 4 Specify the provider-specific configuration parameters.

b. Create the **SecretProviderClass** object by running the following command:

```
$ oc create -f secret-provider-class-aws.yaml
```

4. Create a deployment to use this secret provider class:
  - a. Create a YAML file that defines the **Deployment** object:

#### Example deployment.yaml

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: my-aws-deployment
  namespace: my-namespace
spec:
  replicas: 1
  selector:
    matchLabels:
      app: my-storage
  template:
    metadata:
      labels:
        app: my-storage
    spec:
      serviceAccountName: aws-provider
      containers:
        - name: busybox
          image: k8s.gcr.io/e2e-test-images/busybox:1.29
          command:
            - "/bin/sleep"
            - "10000"
          volumeMounts:
            - name: secrets-store-inline
              mountPath: "/mnt/secrets-store"
              readOnly: true
      volumes:
        - name: secrets-store-inline
          csi:
            driver: secrets-store.csi.k8s.io
  1
  2
```

```
readOnly: true
volumeAttributes:
  secretProviderClass: "my-aws-provider" 3
```

- 1 Specify the name for the deployment.
- 2 Specify the namespace for the deployment. This must be the same namespace as the secret provider class.
- 3 Specify the name of the secret provider class.

- b. Create the **Deployment** object by running the following command:

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

### Verification

- Verify that you can access the secrets from AWS Systems Manager Parameter Store in the pod volume mount:
  - a. List the secrets in the pod mount:

```
$ oc exec busybox-<hash> -n my-namespace -- ls /mnt/secrets-store/
```

#### Example output

```
testParameter
```

- b. View a secret in the pod mount:

```
$ oc exec busybox-<hash> -n my-namespace -- cat /mnt/secrets-store/testSecret
```

#### Example output

```
<secret_value>
```

### Additional resources

- [Configuring the Cloud Credential Operator utility](#)

### 2.7.3.3. Mounting secrets from Azure Key Vault

You can use the Secrets Store CSI Driver Operator to mount secrets from Azure Key Vault to a CSI volume in OpenShift Container Platform. To mount secrets from Azure Key Vault, your cluster must be installed on Microsoft Azure.

### Prerequisites

- Your cluster is installed on Azure.
- You have installed the Secrets Store CSI Driver Operator. See *Installing the Secrets Store CSI driver* for instructions.

- You have configured Azure Key Vault to store the required secrets.
- You have installed the Azure CLI (**az**).
- You have access to the cluster as a user with the **cluster-admin** role.

## Procedure

1. Install the Azure Key Vault provider:
  - a. Create a YAML file with the following configuration for the provider resources:



### IMPORTANT

The Azure Key Vault provider for the Secrets Store CSI driver is an upstream provider.

This configuration is modified from the configuration provided in the upstream [Azure documentation](#) so that it works properly with OpenShift Container Platform. Changes to this configuration might impact functionality.

### Example azure-provider.yaml file

```

apiVersion: v1
kind: ServiceAccount
metadata:
  name: csi-secrets-store-provider-azure
  namespace: openshift-cluster-csi-drivers
---
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRole
metadata:
  name: csi-secrets-store-provider-azure-cluster-role
rules:
- apiGroups: [""]
  resources: ["serviceaccounts/token"]
  verbs: ["create"]
- apiGroups: [""]
  resources: ["serviceaccounts"]
  verbs: ["get"]
- apiGroups: [""]
  resources: ["pods"]
  verbs: ["get"]
- apiGroups: [""]
  resources: ["nodes"]
  verbs: ["get"]
---
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRoleBinding
metadata:
  name: csi-secrets-store-provider-azure-cluster-rolebinding
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: ClusterRole
  name: csi-secrets-store-provider-azure-cluster-role

```

```
subjects:
- kind: ServiceAccount
  name: csi-secrets-store-provider-azure
  namespace: openshift-cluster-csi-drivers
---
apiVersion: apps/v1
kind: DaemonSet
metadata:
  namespace: openshift-cluster-csi-drivers
  name: csi-secrets-store-provider-azure
  labels:
    app: csi-secrets-store-provider-azure
spec:
  updateStrategy:
    type: RollingUpdate
  selector:
    matchLabels:
      app: csi-secrets-store-provider-azure
  template:
    metadata:
      labels:
        app: csi-secrets-store-provider-azure
    spec:
      serviceAccountName: csi-secrets-store-provider-azure
      hostNetwork: true
      containers:
      - name: provider-azure-installer
        image: mcr.microsoft.com/oss/azure/secrets-store/provider-azure:v1.4.1
        imagePullPolicy: IfNotPresent
        args:
        - --endpoint=unix:///provider/azure.sock
        - --construct-pem-chain=true
        - --healthz-port=8989
        - --healthz-path=/healthz
        - --healthz-timeout=5s
      livenessProbe:
        httpGet:
          path: /healthz
          port: 8989
        failureThreshold: 3
        initialDelaySeconds: 5
        timeoutSeconds: 10
        periodSeconds: 30
      resources:
        requests:
          cpu: 50m
          memory: 100Mi
        limits:
          cpu: 50m
          memory: 100Mi
      securityContext:
        allowPrivilegeEscalation: false
        readOnlyRootFilesystem: true
        runAsUser: 0
      capabilities:
        drop:
```

```

- ALL
volumeMounts:
- mountPath: "/provider"
  name: providervol
affinity:
nodeAffinity:
  requiredDuringSchedulingIgnoredDuringExecution:
    nodeSelectorTerms:
    - matchExpressions:
      - key: type
        operator: NotIn
        values:
        - virtual-kubelet
volumes:
- name: providervol
  hostPath:
    path: "/var/run/secrets-store-csi-providers"
tolerations:
- operator: Exists
nodeSelector:
  kubernetes.io/os: linux

```

- b. Grant privileged access to the **csi-secrets-store-provider-azure** service account by running the following command:

```
$ oc adm policy add-scc-to-user privileged -z csi-secrets-store-provider-azure -n openshift-cluster-csi-drivers
```

- c. Create the provider resources by running the following command:

```
$ oc apply -f azure-provider.yaml
```

2. Create a service principal to access the key vault:

- a. Set the service principal client secret as an environment variable by running the following command:

```
$ SERVICE_PRINCIPAL_CLIENT_SECRET="$(az ad sp create-for-rbac --name https://$KEYVAULT_NAME --query 'password' -otsv)"
```

- b. Set the service principal client ID as an environment variable by running the following command:

```
$ SERVICE_PRINCIPAL_CLIENT_ID="$(az ad sp list --display-name https://$KEYVAULT_NAME --query '[0].appId' -otsv)"
```

- c. Create a generic secret with the service principal client secret and ID by running the following command:

```
$ oc create secret generic secrets-store-creds -n my-namespace --from-literal clientId=${SERVICE_PRINCIPAL_CLIENT_ID} --from-literal clientsecret=${SERVICE_PRINCIPAL_CLIENT_SECRET}
```

- d. Apply the **secrets-store.csi.k8s.io/used=true** label to allow the provider to find this **nodePublishSecretRef** secret:

```
$ oc -n my-namespace label secret secrets-store-creds secrets-store.csi.k8s.io/used=true
```

3. Create a secret provider class to define your secrets store provider:

- a. Create a YAML file that defines the **SecretProviderClass** object:

#### Example secret-provider-class-azure.yaml

```
apiVersion: secrets-store.csi.x-k8s.io/v1
kind: SecretProviderClass
metadata:
  name: my-azure-provider
  namespace: my-namespace
spec:
  provider: azure
  parameters:
    usePodIdentity: "false"
    useVMManagedIdentity: "false"
    userAssignedIdentityID: ""
    keyvaultName: "kvname"
  objects: |
    array:
    - |
      objectName: secret1
      objectType: secret
  tenantId: "tid"
```

- 1 Specify the name for the secret provider class.
- 2 Specify the namespace for the secret provider class.
- 3 Specify the provider as **azure**.
- 4 Specify the provider-specific configuration parameters.

- b. Create the **SecretProviderClass** object by running the following command:

```
$ oc create -f secret-provider-class-azure.yaml
```

4. Create a deployment to use this secret provider class:

- a. Create a YAML file that defines the **Deployment** object:

#### Example deployment.yaml

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: my-azure-deployment
  namespace: my-namespace
```

```

spec:
  replicas: 1
  selector:
    matchLabels:
      app: my-storage
  template:
    metadata:
      labels:
        app: my-storage
    spec:
      containers:
        - name: busybox
          image: k8s.gcr.io/e2e-test-images/busybox:1.29
          command:
            - "/bin/sleep"
            - "10000"
          volumeMounts:
            - name: secrets-store-inline
              mountPath: "/mnt/secrets-store"
              readOnly: true
      volumes:
        - name: secrets-store-inline
          csi:
            driver: secrets-store.csi.k8s.io
            readOnly: true
            volumeAttributes:
              secretProviderClass: "my-azure-provider" 3
            nodePublishSecretRef:
              name: secrets-store-creds 4

```

- 1 Specify the name for the deployment.
- 2 Specify the namespace for the deployment. This must be the same namespace as the secret provider class.
- 3 Specify the name of the secret provider class.
- 4 Specify the name of the Kubernetes secret that contains the service principal credentials to access Azure Key Vault.

b. Create the **Deployment** object by running the following command:

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

### Verification

- Verify that you can access the secrets from Azure Key Vault in the pod volume mount:
  - a. List the secrets in the pod mount:

```
$ oc exec busybox-<hash> -n my-namespace -- ls /mnt/secrets-store/
```

### Example output



```
secret1
```

- b. View a secret in the pod mount:

```
$ oc exec busybox-<hash> -n my-namespace -- cat /mnt/secrets-store/secret1
```

### Example output

```
my-secret-value
```

#### 2.7.3.4. Mounting secrets from HashiCorp Vault

You can use the Secrets Store CSI Driver Operator to mount secrets from HashiCorp Vault to a CSI volume in OpenShift Container Platform.



### IMPORTANT

Mounting secrets from HashiCorp Vault by using the Secrets Store CSI Driver Operator has been tested with the following cloud providers:

- Amazon Web Services (AWS)
- Microsoft Azure

Other cloud providers might work, but have not been tested yet. Additional cloud providers might be tested in the future.

### Prerequisites

- You have installed the Secrets Store CSI Driver Operator. See *Installing the Secrets Store CSI driver* for instructions.
- You have installed Helm.
- You have access to the cluster as a user with the **cluster-admin** role.

### Procedure

1. Add the HashiCorp Helm repository by running the following command:

```
$ helm repo add hashicorp https://helm.releases.hashicorp.com
```

2. Update all repositories to ensure that Helm is aware of the latest versions by running the following command:

```
$ helm repo update
```

3. Install the HashiCorp Vault provider:

- a. Create a new project for Vault by running the following command:

```
$ oc new-project vault
```

- b. Label the **vault** namespace for pod security admission by running the following command:

```
$ oc label ns vault security.openshift.io/scc.podSecurityLabelSync=false pod-
security.kubernetes.io/enforce=privileged pod-security.kubernetes.io/audit=privileged
pod-security.kubernetes.io/warn=privileged --overwrite
```

- c. Grant privileged access to the **vault** service account by running the following command:

```
$ oc adm policy add-scc-to-user privileged -z vault -n vault
```

- d. Grant privileged access to the **vault-csi-provider** service account by running the following command:

```
$ oc adm policy add-scc-to-user privileged -z vault-csi-provider -n vault
```

- e. Deploy HashiCorp Vault by running the following command:

```
$ helm install vault hashicorp/vault --namespace=vault \
--set "server.dev.enabled=true" \
--set "injector.enabled=false" \
--set "csi.enabled=true" \
--set "global.openshift=true" \
--set "injector.agentImage.repository=docker.io/hashicorp/vault" \
--set "server.image.repository=docker.io/hashicorp/vault" \
--set "csi.image.repository=docker.io/hashicorp/vault-csi-provider" \
--set "csi.agent.image.repository=docker.io/hashicorp/vault" \
--set "csi.daemonSet.providersDir=/var/run/secrets-store-csi-providers"
```

- f. Patch the **vault-csi-driver** daemon set to set the **securityContext** to **privileged** by running the following command:

```
$ oc patch daemonset -n vault vault-csi-provider --type=json -p='[{"op": "add", "path":
"/spec/template/spec/containers/0/securityContext", "value": {"privileged": true} }]'
```

- g. Verify that the **vault-csi-provider** pods have started properly by running the following command:

```
$ oc get pods -n vault
```

### Example output

```
NAME                READY STATUS RESTARTS AGE
vault-0             1/1   Running 0      24m
vault-csi-provider-87rgw 1/2   Running 0      5s
vault-csi-provider-bd6hp 1/2   Running 0      4s
vault-csi-provider-smlv7 1/2   Running 0      5s
```

4. Configure HashiCorp Vault to store the required secrets:

- a. Create a secret by running the following command:

```
$ oc exec vault-0 --namespace=vault -- vault kv put secret/example1 testSecret1=my-
secret-value
```

- b. Verify that the secret is readable at the path **secret/example1** by running the following command:

```
$ oc exec vault-0 --namespace=vault -- vault kv get secret/example1
```

### Example output

```
= Secret Path =
secret/data/example1

===== Metadata =====
Key          Value
---          -
created_time 2024-04-05T07:05:16.713911211Z
custom_metadata <nil>
deletion_time n/a
destroyed     false
version       1

=== Data ===
Key          Value
---          -
testSecret1 my-secret-value
```

5. Configure Vault to use Kubernetes authentication:

- a. Enable the Kubernetes auth method by running the following command:

```
$ oc exec vault-0 --namespace=vault -- vault auth enable kubernetes
```

### Example output

```
Success! Enabled kubernetes auth method at: kubernetes/
```

- b. Configure the Kubernetes auth method:

- i. Set the token reviewer as an environment variable by running the following command:

```
$ TOKEN_REVIEWER_JWT="$(oc exec vault-0 --namespace=vault -- cat
/var/run/secrets/kubernetes.io/serviceaccount/token)"
```

- ii. Set the Kubernetes service IP address as an environment variable by running the following command:

```
$ KUBERNETES_SERVICE_IP="$(oc get svc kubernetes -o go-template="{{
.spec.clusterIP }}")"
```

- iii. Update the Kubernetes auth method by running the following command:

```
$ oc exec -i vault-0 --namespace=vault -- vault write auth/kubernetes/config \
issuer="https://kubernetes.default.svc.cluster.local" \
token_reviewer_jwt="{TOKEN_REVIEWER_JWT}" \
```

```
kubernetes_host="https://${KUBERNETES_SERVICE_IP}:443" \
kubernetes_ca_cert=@/var/run/secrets/kubernetes.io/serviceaccount/ca.crt
```

### Example output

```
Success! Data written to: auth/kubernetes/config
```

- c. Create a policy for the application by running the following command:

```
$ oc exec -i vault-0 --namespace=vault -- vault policy write csi -<<EOF
path "secret/data/*" {
  capabilities = ["read"]
}
EOF
```

### Example output

```
Success! Uploaded policy: csi
```

- d. Create an authentication role to access the application by running the following command:

```
$ oc exec -i vault-0 --namespace=vault -- vault write auth/kubernetes/role/csi \
bound_service_account_names=default \
bound_service_account_namespaces=default,test-ns,negative-test-ns,my-namespace \
policies=csi \
ttl=20m
```

### Example output

```
Success! Data written to: auth/kubernetes/role/csi
```

- e. Verify that all of the **vault** pods are running properly by running the following command:

```
$ oc get pods -n vault
```

### Example output

NAME	READY	STATUS	RESTARTS	AGE
vault-0	1/1	Running	0	43m
vault-csi-provider-87rgw	2/2	Running	0	19m
vault-csi-provider-bd6hp	2/2	Running	0	19m
vault-csi-provider-smlv7	2/2	Running	0	19m

- f. Verify that all of the **secrets-store-csi-driver** pods are running properly by running the following command:

```
$ oc get pods -n openshift-cluster-csi-drivers | grep -E "secrets"
```

### Example output

```
secrets-store-csi-driver-node-46d2g          3/3   Running   0          45m
```

```

secrets-store-csi-driver-node-d2jjn      3/3   Running 0      45m
secrets-store-csi-driver-node-drmt4     3/3   Running 0      45m
secrets-store-csi-driver-node-j2wlt     3/3   Running 0      45m
secrets-store-csi-driver-node-v9xv4     3/3   Running 0      45m
secrets-store-csi-driver-node-vlz28     3/3   Running 0      45m
secrets-store-csi-driver-operator-84bd699478-fpxrw 1/1   Running 0      47m

```

6. Create a secret provider class to define your secrets store provider:
  - a. Create a YAML file that defines the **SecretProviderClass** object:

#### Example secret-provider-class-vault.yaml

```

apiVersion: secrets-store.csi.x-k8s.io/v1
kind: SecretProviderClass
metadata:
  name: my-vault-provider
  namespace: my-namespace
spec:
  provider: vault
  parameters:
    roleName: "csi"
    vaultAddress: "http://vault.vault:8200"
    objects: |
      - secretPath: "secret/data/example1"
        objectName: "testSecret1"
        secretKey: "testSecret1"

```

- 1 Specify the name for the secret provider class.
- 2 Specify the namespace for the secret provider class.
- 3 Specify the provider as **vault**.
- 4 Specify the provider-specific configuration parameters.

- b. Create the **SecretProviderClass** object by running the following command:

```
$ oc create -f secret-provider-class-vault.yaml
```

7. Create a deployment to use this secret provider class:
  - a. Create a YAML file that defines the **Deployment** object:

#### Example deployment.yaml

```

apiVersion: apps/v1
kind: Deployment
metadata:
  name: busybox-deployment
  namespace: my-namespace
labels:
  app: busybox

```

```

spec:
  replicas: 1
  selector:
    matchLabels:
      app: busybox
  template:
    metadata:
      labels:
        app: busybox
    spec:
      terminationGracePeriodSeconds: 0
      containers:
      - image: registry.k8s.io/e2e-test-images/busybox:1.29-4
        name: busybox
        imagePullPolicy: IfNotPresent
        command:
        - "/bin/sleep"
        - "10000"
        volumeMounts:
        - name: secrets-store-inline
          mountPath: "/mnt/secrets-store"
          readOnly: true
      volumes:
      - name: secrets-store-inline
        csi:
          driver: secrets-store.csi.k8s.io
          readOnly: true
          volumeAttributes:
            secretProviderClass: "my-vault-provider"

```

- 1 Specify the name for the deployment.
- 2 Specify the namespace for the deployment. This must be the same namespace as the secret provider class.
- 3 Specify the name of the secret provider class.

b. Create the **Deployment** object by running the following command:

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

## Verification

- Verify that you can access the secrets from your HashiCorp Vault in the pod volume mount:
  - a. List the secrets in the pod mount by running the following command:

```
$ oc exec busybox-<hash> -n my-namespace -- ls /mnt/secrets-store/
```

## Example output

```
testSecret1
```

b. View a secret in the pod mount by running the following command:

```
$ oc exec busybox-<hash> -n my-namespace -- cat /mnt/secrets-store/testSecret1
```

#### Example output

```
my-secret-value
```

### 2.7.4. Enabling synchronization of mounted content as Kubernetes secrets

You can enable synchronization to create Kubernetes secrets from the content on a mounted volume. An example where you might want to enable synchronization is to use an environment variable in your deployment to reference the Kubernetes secret.



#### WARNING

Do not enable synchronization if you do not want to store your secrets on your OpenShift Container Platform cluster and in etcd. Enable this functionality only if you require it, such as when you want to use environment variables to refer to the secret.

If you enable synchronization, the secrets from the mounted volume are synchronized as Kubernetes secrets after you start a pod that mounts the secrets.

The synchronized Kubernetes secret is deleted when all pods that mounted the content are deleted.

#### Prerequisites

- You have installed the Secrets Store CSI Driver Operator.
- You have installed a secrets store provider.
- You have created the secret provider class.
- You have access to the cluster as a user with the **cluster-admin** role.

#### Procedure

1. Edit the **SecretProviderClass** resource by running the following command:

```
$ oc edit secretproviderclass my-azure-provider 1
```

**1** Replace **my-azure-provider** with the name of your secret provider class.

2. Add the **secretsObjects** section with the configuration for the synchronized Kubernetes secrets:

```
apiVersion: secrets-store.csi.x-k8s.io/v1
```

```

kind: SecretProviderClass
metadata:
  name: my-azure-provider
  namespace: my-namespace
spec:
  provider: azure
  secretObjects:
    - secretName: tlssecret
      type: kubernetes.io/tls
      labels:
        environment: "test"
      data:
        - objectName: tlskey
          key: tls.key
        - objectName: tlscrt
          key: tls.crt
  parameters:
    usePodIdentity: "false"
    keyvaultName: "kvname"
    objects: |
      array:
        - |
          objectName: tlskey
          objectType: secret
        - |
          objectName: tlscrt
          objectType: secret
    tenantId: "tid"

```

- 1 Specify the configuration for synchronized Kubernetes secrets.
- 2 Specify the name of the Kubernetes **Secret** object to create.
- 3 Specify the type of Kubernetes **Secret** object to create. For example, **Opaque** or **kubernetes.io/tls**.
- 4 Specify the object name or alias of the mounted content to synchronize.
- 5 Specify the data field from the specified **objectName** to populate the Kubernetes secret with.

3. Save the file to apply the changes.

### 2.7.5. Viewing the status of secrets in the pod volume mount

You can view detailed information, including the versions, of the secrets in the pod volume mount.

The Secrets Store CSI Driver Operator creates a **SecretProviderClassPodStatus** resource in the same namespace as the pod. You can review this resource to see detailed information, including versions, about the secrets in the pod volume mount.

#### Prerequisites

- You have installed the Secrets Store CSI Driver Operator.



- You have installed a secrets store provider.
- You have created the secret provider class.
- You have deployed a pod that mounts a volume from the Secrets Store CSI Driver Operator.
- You have access to the cluster as a user with the **cluster-admin** role.

### Procedure

- View detailed information about the secrets in a pod volume mount by running the following command:

```
$ oc get secretproviderclasspodstatus <secret_provider_class_pod_status_name> -o yaml
```

1

- 1 The name of the secret provider class pod status object is in the format of **<pod\_name>-<namespace>-<secret\_provider\_class\_name>**.

### Example output

```
...
status:
  mounted: true
  objects:
  - id: secret/tlsCRT
    version: f352293b97da4fa18d96a9528534cb33
  - id: secret/tlskey
    version: 02534bc3d5df481cb138f8b2a13951ef
  podName: busybox-<hash>
  secretProviderClassName: my-azure-provider
  targetPath: /var/lib/kubelet/pods/f0d49c1e-c87a-4beb-888f-
37798456a3e7/volumes/kubernetes.io~csi/secrets-store-inline/mount
```

## 2.7.6. 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.

## 2.8. CREATING AND USING CONFIG MAPS

The following sections define config maps and how to create and use them.

### 2.8.1. Understanding config maps

Many applications require configuration by using some combination of configuration files, command line arguments, and environment variables. In OpenShift Container Platform, these configuration artifacts are decoupled from image content to keep containerized applications portable.

The **ConfigMap** object provides mechanisms to inject containers with configuration data while keeping containers agnostic of OpenShift Container Platform. A config map can be used to store fine-grained information like individual properties or coarse-grained information like entire configuration files or JSON blobs.

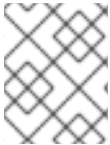
The **ConfigMap** object holds key-value pairs of configuration data that can be consumed in pods or used to store configuration data for system components such as controllers. For example:

#### ConfigMap Object Definition

```
kind: ConfigMap
apiVersion: v1
metadata:
  creationTimestamp: 2016-02-18T19:14:38Z
  name: example-config
  namespace: my-namespace
data: 1
```

```
example.property.1: hello
example.property.2: world
example.property.file: |-
  property.1=value-1
  property.2=value-2
  property.3=value-3
binaryData:
  bar: L3Jvb3QvMTAw 2
```

- 1** Contains the configuration data.
- 2** Points to a file that contains non-UTF8 data, for example, a binary Java keystore file. Enter the file data in Base 64.



## NOTE

You can use the **binaryData** field when you create a config map from a binary file, such as an image.

Configuration data can be consumed in pods in a variety of ways. A config map can be used to:

- Populate environment variable values in containers
- Set command-line arguments in a container
- Populate configuration files in a volume

Users and system components can store configuration data in a config map.

A config map is similar to a secret, but designed to more conveniently support working with strings that do not contain sensitive information.

### Config map restrictions

**A config map must be created before its contents can be consumed in pods.**

Controllers can be written to tolerate missing configuration data. Consult individual components configured by using config maps on a case-by-case basis.

### ConfigMap objects reside in a project.

They can only be referenced by pods in the same project.

**The Kubelet only supports the use of a config map for pods it gets from the API server.**

This includes any pods created by using the CLI, or indirectly from a replication controller. It does not include pods created by using the OpenShift Container Platform node's **--manifest-url** flag, its **--config** flag, or its REST API because these are not common ways to create pods.

## 2.8.2. Creating a config map in the OpenShift Container Platform web console

You can create a config map in the OpenShift Container Platform web console.

### Procedure

- To create a config map as a cluster administrator:
  1. In the Administrator perspective, select **Workloads** → **Config Maps**.
  2. At the top right side of the page, select **Create Config Map**.
  3. Enter the contents of your config map.
  4. Select **Create**.
- To create a config map as a developer:
  1. In the Developer perspective, select **Config Maps**.
  2. At the top right side of the page, select **Create Config Map**.
  3. Enter the contents of your config map.
  4. Select **Create**.

### 2.8.3. Creating a config map by using the CLI

You can use the following command to create a config map from directories, specific files, or literal values.

#### Procedure

- Create a config map:

```
$ oc create configmap <configmap_name> [options]
```

#### 2.8.3.1. Creating a config map from a directory

You can create a config map from a directory by using the **--from-file** flag. This method allows you to use multiple files within a directory to create a config map.

Each file in the directory is used to populate a key in the config map, where the name of the key is the file name, and the value of the key is the content of the file.

For example, the following command creates a config map with the contents of the **example-files** directory:

```
$ oc create configmap game-config --from-file=example-files/
```

View the keys in the config map:

```
$ oc describe configmaps game-config
```

#### Example output

```
Name:      game-config
Namespace: default
Labels:    <none>
Annotations: <none>
```

## Data

```
game.properties: 158 bytes
ui.properties:   83 bytes
```

You can see that the two keys in the map are created from the file names in the directory specified in the command. The content of those keys might be large, so the output of **oc describe** only shows the names of the keys and their sizes.

## Prerequisite

- You must have a directory with files that contain the data you want to populate a config map with.

The following procedure uses these example files: **game.properties** and **ui.properties**:

```
$ cat example-files/game.properties
```

### Example output

```
enemies=aliens
lives=3
enemies.cheat=true
enemies.cheat.level=noGoodRotten
secret.code.passphrase=UUDDLRLRBABAS
secret.code.allowed=true
secret.code.lives=30
```

```
$ cat example-files/ui.properties
```

### Example output

```
color.good=purple
color.bad=yellow
allow.textmode=true
how.nice.to.look=fairlyNice
```

## Procedure

- Create a config map holding the content of each file in this directory by entering the following command:

```
$ oc create configmap game-config \
  --from-file=example-files/
```

## Verification

- Enter the **oc get** command for the object with the **-o** option to see the values of the keys:

```
$ oc get configmaps game-config -o yaml
```

### Example output

```

apiVersion: v1
data:
  game.properties: |-
    enemies=aliens
    lives=3
    enemies.cheat=true
    enemies.cheat.level=noGoodRotten
    secret.code.passphrase=UUDDLRLRBABAS
    secret.code.allowed=true
    secret.code.lives=30
  ui.properties: |
    color.good=purple
    color.bad=yellow
    allow.textmode=true
    how.nice.to.look=fairlyNice
kind: ConfigMap
metadata:
  creationTimestamp: 2016-02-18T18:34:05Z
  name: game-config
  namespace: default
  resourceVersion: "407"
  selflink: /api/v1/namespaces/default/configmaps/game-config
  uid: 30944725-d66e-11e5-8cd0-68f728db1985

```

### 2.8.3.2. Creating a config map from a file

You can create a config map from a file by using the **--from-file** flag. You can pass the **--from-file** option multiple times to the CLI.

You can also specify the key to set in a config map for content imported from a file by passing a **key=value** expression to the **--from-file** option. For example:

```
$ oc create configmap game-config-3 --from-file=game-special-key=example-files/game.properties
```



#### NOTE

If you create a config map from a file, you can include files containing non-UTF8 data that are placed in this field without corrupting the non-UTF8 data. OpenShift Container Platform detects binary files and transparently encodes the file as **MIME**. On the server, the **MIME** payload is decoded and stored without corrupting the data.

#### Prerequisite

- You must have a directory with files that contain the data you want to populate a config map with.

The following procedure uses these example files: **game.properties** and **ui.properties**:

```
$ cat example-files/game.properties
```

#### Example output

```

enemies=aliens
lives=3

```

```

enemies.cheat=true
enemies.cheat.level=noGoodRotten
secret.code.passphrase=UUDDLRLRBABAS
secret.code.allowed=true
secret.code.lives=30

```

```
$ cat example-files/ui.properties
```

### Example output

```

color.good=purple
color.bad=yellow
allow.textmode=true
how.nice.to.look=fairlyNice

```

### Procedure

- Create a config map by specifying a specific file:

```

$ oc create configmap game-config-2 \
  --from-file=example-files/game.properties \
  --from-file=example-files/ui.properties

```

- Create a config map by specifying a key-value pair:

```

$ oc create configmap game-config-3 \
  --from-file=game-special-key=example-files/game.properties

```

### Verification

- Enter the **oc get** command for the object with the **-o** option to see the values of the keys from the file:

```
$ oc get configmaps game-config-2 -o yaml
```

### Example output

```

apiVersion: v1
data:
  game.properties: |-
    enemies=aliens
    lives=3
    enemies.cheat=true
    enemies.cheat.level=noGoodRotten
    secret.code.passphrase=UUDDLRLRBABAS
    secret.code.allowed=true
    secret.code.lives=30
  ui.properties: |
    color.good=purple
    color.bad=yellow
    allow.textmode=true
    how.nice.to.look=fairlyNice

```

```
kind: ConfigMap
metadata:
  creationTimestamp: 2016-02-18T18:52:05Z
  name: game-config-2
  namespace: default
  resourceVersion: "516"
  selflink: /api/v1/namespaces/default/configmaps/game-config-2
  uid: b4952dc3-d670-11e5-8cd0-68f728db1985
```

- Enter the **oc get** command for the object with the **-o** option to see the values of the keys from the key-value pair:

```
$ oc get configmaps game-config-3 -o yaml
```

### Example output

```
apiVersion: v1
data:
  game-special-key: |- 1
    enemies=aliens
    lives=3
    enemies.cheat=true
    enemies.cheat.level=noGoodRotten
    secret.code.passphrase=UUDDLRLRBABAS
    secret.code.allowed=true
    secret.code.lives=30
kind: ConfigMap
metadata:
  creationTimestamp: 2016-02-18T18:54:22Z
  name: game-config-3
  namespace: default
  resourceVersion: "530"
  selflink: /api/v1/namespaces/default/configmaps/game-config-3
  uid: 05f8da22-d671-11e5-8cd0-68f728db1985
```

- 1** This is the key that you set in the preceding step.

### 2.8.3.3. Creating a config map from literal values

You can supply literal values for a config map.

The **--from-literal** option takes a **key=value** syntax, which allows literal values to be supplied directly on the command line.

#### Procedure

- Create a config map by specifying a literal value:

```
$ oc create configmap special-config \
  --from-literal=special.how=very \
  --from-literal=special.type=charm
```



## Verification

- Enter the **oc get** command for the object with the **-o** option to see the values of the keys:

```
$ oc get configmaps special-config -o yaml
```

### Example output

```
apiVersion: v1
data:
  special.how: very
  special.type: charm
kind: ConfigMap
metadata:
  creationTimestamp: 2016-02-18T19:14:38Z
  name: special-config
  namespace: default
  resourceVersion: "651"
  selflink: /api/v1/namespaces/default/configmaps/special-config
  uid: dadce046-d673-11e5-8cd0-68f728db1985
```

## 2.8.4. Use cases: Consuming config maps in pods

The following sections describe some uses cases when consuming **ConfigMap** objects in pods.

### 2.8.4.1. Populating environment variables in containers by using config maps

You can use config maps to populate individual environment variables in containers or to populate environment variables in containers from all keys that form valid environment variable names.

As an example, consider the following config map:

#### ConfigMap with two environment variables

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: special-config 1
  namespace: default 2
data:
  special.how: very 3
  special.type: charm 4
```

- 1** Name of the config map.
- 2** The project in which the config map resides. Config maps can only be referenced by pods in the same project.
- 3** **4** Environment variables to inject.

#### ConfigMap with one environment variable

```

apiVersion: v1
kind: ConfigMap
metadata:
  name: env-config 1
  namespace: default
data:
  log_level: INFO 2

```

- 1 Name of the config map.
- 2 Environment variable to inject.

## Procedure

- You can consume the keys of this **ConfigMap** in a pod using **configMapKeyRef** sections.

### Sample Pod specification configured to inject specific environment variables

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-test-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: test-container
    image: gcr.io/google_containers/busybox
    command: [ "/bin/sh", "-c", "env" ]
    env: 1
    - name: SPECIAL_LEVEL_KEY 2
      valueFrom:
        configMapKeyRef:
          name: special-config 3
          key: special.how 4
    - name: SPECIAL_TYPE_KEY
      valueFrom:
        configMapKeyRef:
          name: special-config 5
          key: special.type 6
          optional: true 7
    envFrom: 8
    - configMapRef:
        name: env-config 9
  securityContext:
    allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
  restartPolicy: Never

```

- 1 Stanza to pull the specified environment variables from a **ConfigMap**.
- 2 Name of a pod environment variable that you are injecting a key's value into.
- 3 5 Name of the **ConfigMap** to pull specific environment variables from.
- 4 6 Environment variable to pull from the **ConfigMap**.
- 7 Makes the environment variable optional. As optional, the pod will be started even if the specified **ConfigMap** and keys do not exist.
- 8 Stanza to pull all environment variables from a **ConfigMap**.
- 9 Name of the **ConfigMap** to pull all environment variables from.

When this pod is run, the pod logs will include the following output:

```
SPECIAL_LEVEL_KEY=very
log_level=INFO
```



#### NOTE

**SPECIAL\_TYPE\_KEY=charm** is not listed in the example output because **optional: true** is set.

### 2.8.4.2. Setting command-line arguments for container commands with config maps

You can use a config map to set the value of the commands or arguments in a container by using the Kubernetes substitution syntax **\$(VAR\_NAME)**.

As an example, consider the following config map:

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: special-config
  namespace: default
data:
  special.how: very
  special.type: charm
```

#### Procedure

- To inject values into a command in a container, you must consume the keys you want to use as environment variables. Then you can refer to them in a container's command using the **\$(VAR\_NAME)** syntax.

#### Sample pod specification configured to inject specific environment variables

```
apiVersion: v1
kind: Pod
metadata:
  name: dapi-test-pod
```

```

spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
    - name: test-container
      image: gcr.io/google_containers/busybox
      command: [ "/bin/sh", "-c", "echo $(SPECIAL_LEVEL_KEY) $(SPECIAL_TYPE_KEY)" ]
      1
      env:
        - name: SPECIAL_LEVEL_KEY
          valueFrom:
            configMapKeyRef:
              name: special-config
              key: special.how
        - name: SPECIAL_TYPE_KEY
          valueFrom:
            configMapKeyRef:
              name: special-config
              key: special.type
      securityContext:
        allowPrivilegeEscalation: false
        capabilities:
          drop: [ALL]
      restartPolicy: Never

```

- 1 Inject the values into a command in a container using the keys you want to use as environment variables.

When this pod is run, the output from the echo command run in the test-container container is as follows:

```
very charm
```

### 2.8.4.3. Injecting content into a volume by using config maps

You can inject content into a volume by using config maps.

#### Example ConfigMap custom resource (CR)

```

apiVersion: v1
kind: ConfigMap
metadata:
  name: special-config
  namespace: default
data:
  special.how: very
  special.type: charm

```

#### Procedure

You have a couple different options for injecting content into a volume by using config maps.

- The most basic way to inject content into a volume by using a config map is to populate the volume with files where the key is the file name and the content of the file is the value of the key:

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-test-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
    - name: test-container
      image: gcr.io/google_containers/busybox
      command: [ "/bin/sh", "-c", "cat", "/etc/config/special.how" ]
      volumeMounts:
        - name: config-volume
          mountPath: /etc/config
      securityContext:
        allowPrivilegeEscalation: false
        capabilities:
          drop: [ALL]
  volumes:
    - name: config-volume
      configMap:
        name: special-config 1
      restartPolicy: Never

```

**1** File containing key.

When this pod is run, the output of the cat command will be:

```

very

```

- You can also control the paths within the volume where config map keys are projected:

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-test-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
    - name: test-container
      image: gcr.io/google_containers/busybox
      command: [ "/bin/sh", "-c", "cat", "/etc/config/path/to/special-key" ]
      volumeMounts:
        - name: config-volume
          mountPath: /etc/config

```

```

securityContext:
  allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]
volumes:
- name: config-volume
  configMap:
    name: special-config
    items:
    - key: special.how
      path: path/to/special-key 1
restartPolicy: Never

```

**1** Path to config map key.

When this pod is run, the output of the cat command will be:

```
very
```

## 2.9. USING DEVICE PLUGINS TO ACCESS EXTERNAL RESOURCES WITH PODS

Device plugins allow you to use a particular device type (GPU, InfiniBand, or other similar computing resources that require vendor-specific initialization and setup) in your OpenShift Container Platform pod without needing to write custom code.

### 2.9.1. Understanding device plugins

The device plugin provides a consistent and portable solution to consume hardware devices across clusters. The device plugin provides support for these devices through an extension mechanism, which makes these devices available to Containers, provides health checks of these devices, and securely shares them.



#### IMPORTANT

OpenShift Container Platform supports the device plugin API, but the device plugin Containers are supported by individual vendors.

A device plugin is a gRPC service running on the nodes (external to the **kubelet**) that is responsible for managing specific hardware resources. Any device plugin must support following remote procedure calls (RPCs):

```

service DevicePlugin {
  // GetDevicePluginOptions returns options to be communicated with Device
  // Manager
  rpc GetDevicePluginOptions(Empty) returns (DevicePluginOptions) {}

  // ListAndWatch returns a stream of List of Devices
  // Whenever a Device state change or a Device disappears, ListAndWatch
  // returns the new list
  rpc ListAndWatch(Empty) returns (stream ListAndWatchResponse) {}
}

```

```

// Allocate is called during container creation so that the Device
// Plug-in can run device specific operations and instruct Kubelet
// of the steps to make the Device available in the container
rpc Allocate(AllocateRequest) returns (AllocateResponse) {}

// PreStartcontainer is called, if indicated by Device Plug-in during
// registration phase, before each container start. Device plug-in
// can run device specific operations such as resetting the device
// before making devices available to the container
rpc PreStartcontainer(PreStartcontainerRequest) returns (PreStartcontainerResponse) {}
}

```

### Example device plugins

- [Nvidia GPU device plugin for COS-based operating system](#)
- [Nvidia official GPU device plugin](#)
- [Solarflare device plugin](#)
- [KubeVirt device plugins: vfio and kvm](#)
- [Kubernetes device plugin for IBM® Crypto Express \(CEX\) cards](#)



#### NOTE

For easy device plugin reference implementation, there is a stub device plugin in the Device Manager code:

[vendor/k8s.io/kubernetes/pkg/kubelet/cm/deviceplugin/device\\_plugin\\_stub.go](https://github.com/kubernetes/kubernetes/blob/master/vendor/k8s.io/kubernetes/pkg/kubelet/cm/deviceplugin/device_plugin_stub.go).

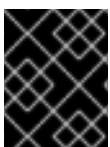
### 2.9.1.1. Methods for deploying a device plugin

- Daemon sets are the recommended approach for device plugin deployments.
- Upon start, the device plugin will try to create a UNIX domain socket at `/var/lib/kubelet/device-plugin/` on the node to serve RPCs from Device Manager.
- Since device plugins must manage hardware resources, access to the host file system, as well as socket creation, they must be run in a privileged security context.
- More specific details regarding deployment steps can be found with each device plugin implementation.

### 2.9.2. Understanding the Device Manager

Device Manager provides a mechanism for advertising specialized node hardware resources with the help of plugins known as device plugins.

You can advertise specialized hardware without requiring any upstream code changes.



#### IMPORTANT

OpenShift Container Platform supports the device plugin API, but the device plugin Containers are supported by individual vendors.

Device Manager advertises devices as **Extended Resources**. User pods can consume devices, advertised by Device Manager, using the same **Limit/Request** mechanism, which is used for requesting any other **Extended Resource**.

Upon start, the device plugin registers itself with Device Manager invoking **Register** on the `/var/lib/kubelet/device-plugins/kubelet.sock` and starts a gRPC service at `/var/lib/kubelet/device-plugins/<plugin>.sock` for serving Device Manager requests.

Device Manager, while processing a new registration request, invokes **ListAndWatch** remote procedure call (RPC) at the device plugin service. In response, Device Manager gets a list of **Device** objects from the plugin over a gRPC stream. Device Manager will keep watching on the stream for new updates from the plugin. On the plugin side, the plugin will also keep the stream open and whenever there is a change in the state of any of the devices, a new device list is sent to the Device Manager over the same streaming connection.

While handling a new pod admission request, Kubelet passes requested **Extended Resources** to the Device Manager for device allocation. Device Manager checks in its database to verify if a corresponding plugin exists or not. If the plugin exists and there are free allocatable devices as well as per local cache, **Allocate** RPC is invoked at that particular device plugin.

Additionally, device plugins can also perform several other device-specific operations, such as driver installation, device initialization, and device resets. These functionalities vary from implementation to implementation.

### 2.9.3. Enabling Device Manager

Enable Device Manager to implement a device plugin to advertise specialized hardware without any upstream code changes.

Device Manager provides a mechanism for advertising specialized node hardware resources with the help of plugins known as device plugins.

1. Obtain the label associated with the static **MachineConfigPool** CRD for the type of node you want to configure by entering the following command. Perform one of the following steps:
  - a. View the machine config:

```
# oc describe machineconfig <name>
```

For example:

```
# oc describe machineconfig 00-worker
```

#### Example output

```
Name:      00-worker
Namespace:
Labels:    machineconfiguration.openshift.io/role=worker 1
```

- 1** Label required for the Device Manager.

#### Procedure

1. Create a custom resource (CR) for your configuration change.



## Sample configuration for a Device Manager CR

```

apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: devicemgr ❶
spec:
  machineConfigPoolSelector:
    matchLabels:
      machineconfiguration.openshift.io: devicemgr ❷
  kubeletConfig:
    feature-gates:
      - DevicePlugins=true ❸

```

- ❶ Assign a name to CR.
- ❷ Enter the label from the Machine Config Pool.
- ❸ Set **DevicePlugins** to 'true`.

2. Create the Device Manager:

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

### Example output

```
kubeletconfig.machineconfiguration.openshift.io/devicemgr created
```

3. Ensure that Device Manager was actually enabled by confirming that `/var/lib/kubelet/device-plugins/kubelet.sock` is created on the node. This is the UNIX domain socket on which the Device Manager gRPC server listens for new plugin registrations. This sock file is created when the Kubelet is started only if Device Manager is enabled.

## 2.10. INCLUDING POD PRIORITY IN POD SCHEDULING DECISIONS

You can enable pod priority and preemption in your cluster. Pod priority indicates the importance of a pod relative to other pods and queues the pods based on that priority. pod preemption allows the cluster to evict, or preempt, lower-priority pods so that higher-priority pods can be scheduled if there is no available space on a suitable node pod priority also affects the scheduling order of pods and out-of-resource eviction ordering on the node.

To use priority and preemption, you create priority classes that define the relative weight of your pods. Then, reference a priority class in the pod specification to apply that weight for scheduling.

### 2.10.1. Understanding pod priority

When you use the Pod Priority and Preemption feature, the scheduler orders pending pods by their priority, and a pending pod is placed ahead of other pending pods with lower priority in the scheduling queue. As a result, the higher priority pod might be scheduled sooner than pods with lower priority if its scheduling requirements are met. If a pod cannot be scheduled, scheduler continues to schedule other lower priority pods.

### 2.10.1.1. Pod priority classes

You can assign pods a priority class, which is a non-namespaced object that defines a mapping from a name to the integer value of the priority. The higher the value, the higher the priority.

A priority class object can take any 32-bit integer value smaller than or equal to 1000000000 (one billion). Reserve numbers larger than or equal to one billion for critical pods that must not be preempted or evicted. By default, OpenShift Container Platform has two reserved priority classes for critical system pods to have guaranteed scheduling.

```
$ oc get priorityclasses
```

#### Example output

NAME	VALUE	GLOBAL-DEFAULT	AGE
system-node-critical	2000001000	false	72m
system-cluster-critical	2000000000	false	72m
openshift-user-critical	1000000000	false	3d13h
cluster-logging	1000000	false	29s

- **system-node-critical** - This priority class has a value of 2000001000 and is used for all pods that should never be evicted from a node. Examples of pods that have this priority class are **ovnkube-node**, and so forth. A number of critical components include the **system-node-critical** priority class by default, for example:
  - master-api
  - master-controller
  - master-etcd
  - ovn-kubernetes
  - sync
- **system-cluster-critical** - This priority class has a value of 2000000000 (two billion) and is used with pods that are important for the cluster. Pods with this priority class can be evicted from a node in certain circumstances. For example, pods configured with the **system-node-critical** priority class can take priority. However, this priority class does ensure guaranteed scheduling. Examples of pods that can have this priority class are fluentd, add-on components like descheduler, and so forth. A number of critical components include the **system-cluster-critical** priority class by default, for example:
  - fluentd
  - metrics-server
  - descheduler
- **openshift-user-critical** - You can use the **priorityClassName** field with important pods that cannot bind their resource consumption and do not have predictable resource consumption behavior. Prometheus pods under the **openshift-monitoring** and **openshift-user-workload-monitoring** namespaces use the **openshift-user-critical priorityClassName**. Monitoring workloads use **system-critical** as their first **priorityClass**, but this causes problems when

monitoring uses excessive memory and the nodes cannot evict them. As a result, monitoring drops priority to give the scheduler flexibility, moving heavy workloads around to keep critical nodes operating.

- **cluster-logging** - This priority is used by Fluentd to make sure Fluentd pods are scheduled to nodes over other apps.

### 2.10.1.2. Pod priority names

After you have one or more priority classes, you can create pods that specify a priority class name in a **Pod** spec. The priority admission controller uses the priority class name field to populate the integer value of the priority. If the named priority class is not found, the pod is rejected.

## 2.10.2. Understanding pod preemption

When a developer creates a pod, the pod goes into a queue. If the developer configured the pod for pod priority or preemption, the scheduler picks a pod from the queue and tries to schedule the pod on a node. If the scheduler cannot find space on an appropriate node that satisfies all the specified requirements of the pod, preemption logic is triggered for the pending pod.

When the scheduler preempts one or more pods on a node, the **nominatedNodeName** field of higher-priority **Pod** spec is set to the name of the node, along with the **nodename** field. The scheduler uses the **nominatedNodeName** field to keep track of the resources reserved for pods and also provides information to the user about preemptions in the clusters.

After the scheduler preempts a lower-priority pod, the scheduler honors the graceful termination period of the pod. If another node becomes available while scheduler is waiting for the lower-priority pod to terminate, the scheduler can schedule the higher-priority pod on that node. As a result, the **nominatedNodeName** field and **nodeName** field of the **Pod** spec might be different.

Also, if the scheduler preempts pods on a node and is waiting for termination, and a pod with a higher-priority pod than the pending pod needs to be scheduled, the scheduler can schedule the higher-priority pod instead. In such a case, the scheduler clears the **nominatedNodeName** of the pending pod, making the pod eligible for another node.

Preemption does not necessarily remove all lower-priority pods from a node. The scheduler can schedule a pending pod by removing a portion of the lower-priority pods.

The scheduler considers a node for pod preemption only if the pending pod can be scheduled on the node.

### 2.10.2.1. Non-preempting priority classes

Pods with the preemption policy set to **Never** are placed in the scheduling queue ahead of lower-priority pods, but they cannot preempt other pods. A non-preempting pod waiting to be scheduled stays in the scheduling queue until sufficient resources are free and it can be scheduled. Non-preempting pods, like other pods, are subject to scheduler back-off. This means that if the scheduler tries unsuccessfully to schedule these pods, they are retried with lower frequency, allowing other pods with lower priority to be scheduled before them.

Non-preempting pods can still be preempted by other, high-priority pods.

### 2.10.2.2. Pod preemption and other scheduler settings

If you enable pod priority and preemption, consider your other scheduler settings:

## Pod priority and pod disruption budget

A pod disruption budget specifies the minimum number or percentage of replicas that must be up at a time. If you specify pod disruption budgets, OpenShift Container Platform respects them when preempting pods at a best effort level. The scheduler attempts to preempt pods without violating the pod disruption budget. If no such pods are found, lower-priority pods might be preempted despite their pod disruption budget requirements.

## Pod priority and pod affinity

Pod affinity requires a new pod to be scheduled on the same node as other pods with the same label.

If a pending pod has inter-pod affinity with one or more of the lower-priority pods on a node, the scheduler cannot preempt the lower-priority pods without violating the affinity requirements. In this case, the scheduler looks for another node to schedule the pending pod. However, there is no guarantee that the scheduler can find an appropriate node and pending pod might not be scheduled.

To prevent this situation, carefully configure pod affinity with equal-priority pods.

### 2.10.2.3. Graceful termination of preempted pods

When preempting a pod, the scheduler waits for the pod graceful termination period to expire, allowing the pod to finish working and exit. If the pod does not exit after the period, the scheduler kills the pod. This graceful termination period creates a time gap between the point that the scheduler preempts the pod and the time when the pending pod can be scheduled on the node.

To minimize this gap, configure a small graceful termination period for lower-priority pods.

### 2.10.3. Configuring priority and preemption

You apply pod priority and preemption by creating a priority class object and associating pods to the priority by using the **priorityClassName** in your pod specs.



#### NOTE

You cannot add a priority class directly to an existing scheduled pod.

## Procedure

To configure your cluster to use priority and preemption:

1. Create one or more priority classes:
  - a. Create a YAML file similar to the following:

```
apiVersion: scheduling.k8s.io/v1
kind: PriorityClass
metadata:
  name: high-priority 1
value: 1000000 2
preemptionPolicy: PreemptLowerPriority 3
globalDefault: false 4
description: "This priority class should be used for XYZ service pods only." 5
```

- 1 The name of the priority class object.

- 2 The priority value of the object.
- 3 Optional. Specifies whether this priority class is preempting or non-preempting. The preemption policy defaults to **PreemptLowerPriority**, which allows pods of that priority class to preempt lower-priority pods. If the preemption policy is set to **Never**, pods in that priority class are non-preempting.
- 4 Optional. Specifies whether this priority class should be used for pods without a priority class name specified. This field is **false** by default. Only one priority class with **globalDefault** set to **true** can exist in the cluster. If there is no priority class with **globalDefault:true**, the priority of pods with no priority class name is zero. Adding a priority class with **globalDefault:true** affects only pods created after the priority class is added and does not change the priorities of existing pods.
- 5 Optional. Describes which pods developers should use with this priority class. Enter an arbitrary text string.

b. Create the priority class:

```
$ oc create -f <file-name>.yaml
```

2. Create a pod spec to include the name of a priority class:

a. Create a YAML file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: nginx
  labels:
    env: test
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: nginx
    image: nginx
    imagePullPolicy: IfNotPresent
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
    priorityClassName: high-priority 1
```

1 Specify the priority class to use with this pod.

b. Create the pod:

```
$ oc create -f <file-name>.yaml
```

You can add the priority name directly to the pod configuration or to a pod template.

## 2.11. PLACING PODS ON SPECIFIC NODES USING NODE SELECTORS

A *node selector* specifies a map of key-value pairs. The rules are defined using custom labels on nodes and selectors specified in pods.

For the pod to be eligible to run on a node, the pod must have the indicated key-value pairs as the label on the node.

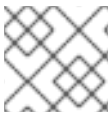
If you are using node affinity and node selectors in the same pod configuration, see the important considerations below.

### 2.11.1. Using node selectors to control pod placement

You can use node selectors on pods and labels on nodes to control where the pod is scheduled. With node selectors, OpenShift Container Platform schedules the pods on nodes that contain matching labels.

You add labels to a node, a compute machine set, or a machine config. Adding the label to the compute machine set ensures that if the node or machine goes down, new nodes have the label. Labels added to a node or machine config do not persist if the node or machine goes down.

To add node selectors to an existing pod, add a node selector to the controlling object for that pod, such as a **ReplicaSet** object, **DaemonSet** object, **StatefulSet** object, **Deployment** object, or **DeploymentConfig** object. Any existing pods under that controlling object are recreated on a node with a matching label. If you are creating a new pod, you can add the node selector directly to the pod spec. If the pod does not have a controlling object, you must delete the pod, edit the pod spec, and recreate the pod.



#### NOTE

You cannot add a node selector directly to an existing scheduled pod.

### Prerequisites

To add a node selector to existing pods, determine the controlling object for that pod. For example, the **router-default-66d5cf9464-m2g75** pod is controlled by the **router-default-66d5cf9464** replica set:

```
$ oc describe pod router-default-66d5cf9464-7pwkc
```

### Example output

```
kind: Pod
apiVersion: v1
metadata:
# ...
Name:          router-default-66d5cf9464-7pwkc
Namespace:    openshift-ingress
# ...
Controlled By:  ReplicaSet/router-default-66d5cf9464
# ...
```

The web console lists the controlling object under **ownerReferences** in the pod YAML:

```
apiVersion: v1
```

```

kind: Pod
metadata:
  name: router-default-66d5cf9464-7pwkc
# ...
ownerReferences:
- apiVersion: apps/v1
  kind: ReplicaSet
  name: router-default-66d5cf9464
  uid: d81dd094-da26-11e9-a48a-128e7edf0312
  controller: true
  blockOwnerDeletion: true
# ...

```

## Procedure

1. Add labels to a node by using a compute machine set or editing the node directly:
  - Use a **MachineSet** object to add labels to nodes managed by the compute machine set when a node is created:
    - a. Run the following command to add labels to a **MachineSet** object:

```

$ oc patch MachineSet <name> --type='json' -
p='[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"<key>="
<value>","<key>="<value>"}]}]' -n openshift-machine-api

```

For example:

```

$ oc patch MachineSet abc612-msrtw-worker-us-east-1c --type='json' -
p='[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"type":"user-
node","region":"east"}}]' -n openshift-machine-api

```

## TIP

You can alternatively apply the following YAML to add labels to a compute machine set:

```

apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  name: xf2bd-infra-us-east-2a
  namespace: openshift-machine-api
spec:
  template:
    spec:
      metadata:
        labels:
          region: "east"
          type: "user-node"
# ...

```

- b. Verify that the labels are added to the **MachineSet** object by using the **oc edit** command:  
For example:

■

```
$ oc edit MachineSet abc612-msrtw-worker-us-east-1c -n openshift-machine-api
```

### Example MachineSet object

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet

# ...

spec:
# ...
  template:
    metadata:
# ...
      spec:
        metadata:
          labels:
            region: east
            type: user-node
# ...
```

- Add labels directly to a node:
  - a. Edit the **Node** object for the node:

```
$ oc label nodes <name> <key>=<value>
```

For example, to label a node:

```
$ oc label nodes ip-10-0-142-25.ec2.internal type=user-node region=east
```

### TIP

You can alternatively apply the following YAML to add labels to a node:

```
kind: Node
apiVersion: v1
metadata:
  name: hello-node-6fbccf8d9
  labels:
    type: "user-node"
    region: "east"
# ...
```

- b. Verify that the labels are added to the node:

```
$ oc get nodes -l type=user-node,region=east
```

### Example output

```
NAME                                STATUS ROLES  AGE  VERSION
ip-10-0-142-25.ec2.internal  Ready  worker  17m  v1.30.3
```



## 2. Add the matching node selector to a pod:

- To add a node selector to existing and future pods, add a node selector to the controlling object for the pods:

### Example ReplicaSet object with labels

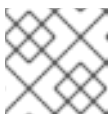
```
kind: ReplicaSet
apiVersion: apps/v1
metadata:
  name: hello-node-6fbccf8d9
  # ...
spec:
  # ...
  template:
    metadata:
      creationTimestamp: null
      labels:
        ingresscontroller.operator.openshift.io/deployment-ingresscontroller: default
        pod-template-hash: 66d5cf9464
    spec:
      nodeSelector:
        kubernetes.io/os: linux
        node-role.kubernetes.io/worker: "
        type: user-node ①
      # ...
```

- ① Add the node selector.

- To add a node selector to a specific, new pod, add the selector to the **Pod** object directly:

### Example Pod object with a node selector

```
apiVersion: v1
kind: Pod
metadata:
  name: hello-node-6fbccf8d9
  # ...
spec:
  nodeSelector:
    region: east
    type: user-node
  # ...
```



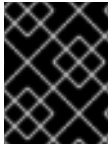
#### NOTE

You cannot add a node selector directly to an existing scheduled pod.

## 2.12. RUN ONCE DURATION OVERRIDE OPERATOR

### 2.12.1. Run Once Duration Override Operator overview

You can use the Run Once Duration Override Operator to specify a maximum time limit that run-once pods can be active for.



## IMPORTANT

The Run Once Duration Override Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.

### 2.12.1.1. About the Run Once Duration Override Operator

OpenShift Container Platform relies on run-once pods to perform tasks such as deploying a pod or performing a build. Run-once pods are pods that have a **RestartPolicy** of **Never** or **OnFailure**.

Cluster administrators can use the Run Once Duration Override Operator to force a limit on the time that those run-once pods can be active. After the time limit expires, the cluster will try to actively terminate those pods. The main reason to have such a limit is to prevent tasks such as builds to run for an excessive amount of time.

To apply the run-once duration override from the Run Once Duration Override Operator to run-once pods, you must enable it on each applicable namespace.

If both the run-once pod and the Run Once Duration Override Operator have their **activeDeadlineSeconds** value set, the lower of the two values is used.

### 2.12.2. Run Once Duration Override Operator release notes

Cluster administrators can use the Run Once Duration Override Operator to force a limit on the time that run-once pods can be active. After the time limit expires, the cluster tries to terminate the run-once pods. The main reason to have such a limit is to prevent tasks such as builds to run for an excessive amount of time.

To apply the run-once duration override from the Run Once Duration Override Operator to run-once pods, you must enable it on each applicable namespace.

These release notes track the development of the Run Once Duration Override Operator for OpenShift Container Platform.

For an overview of the Run Once Duration Override Operator, see [About the Run Once Duration Override Operator](#).

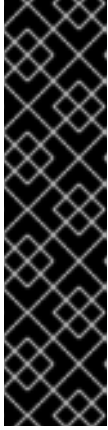
#### 2.12.2.1. Run Once Duration Override Operator 1.1.1

Issued: 2024-07-01

The following advisory is available for the Run Once Duration Override Operator 1.1.1: [RHSA-2024:1616](#)

##### 2.12.2.1.1. New features and enhancements

- You can install and use the Run Once Duration Override Operator in an OpenShift Container Platform cluster running in FIPS mode.



## IMPORTANT

To enable FIPS mode for your cluster, you must run the installation program from a Red Hat Enterprise Linux (RHEL) computer configured to operate in FIPS mode. For more information about configuring FIPS mode on RHEL, see [Switching RHEL to FIPS mode](#).

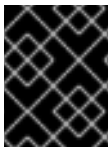
When running Red Hat Enterprise Linux (RHEL) or Red Hat Enterprise Linux CoreOS (RHCOS) booted in FIPS mode, OpenShift Container Platform core components use the RHEL cryptographic libraries that have been submitted to NIST for FIPS 140-2/140-3 Validation on only the x86\_64, ppc64le, and s390x architectures.

### 2.12.2.1.2. Bug fixes

- This release of the Run Once Duration Override Operator addresses several Common Vulnerabilities and Exposures (CVEs).

### 2.12.3. Overriding the active deadline for run-once pods

You can use the Run Once Duration Override Operator to specify a maximum time limit that run-once pods can be active for. By enabling the run-once duration override on a namespace, all future run-once pods created or updated in that namespace have their **activeDeadlineSeconds** field set to the value specified by the Run Once Duration Override Operator.



## IMPORTANT

The Run Once Duration Override Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.

#### 2.12.3.1. Installing the Run Once Duration Override Operator

You can use the web console to install the Run Once Duration Override Operator.

#### Prerequisites

- You have access to the cluster with **cluster-admin** privileges.
- You have access to the OpenShift Container Platform web console.

#### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Create the required namespace for the Run Once Duration Override Operator.
  - a. Navigate to **Administration** → **Namespaces** and click **Create Namespace**.
  - b. Enter **openshift-run-once-duration-override-operator** in the **Name** field and click **Create**.
3. Install the Run Once Duration Override Operator.
  - a. Navigate to **Operators** → **OperatorHub**.
  - b. Enter **Run Once Duration Override Operator** into the filter box.

- c. Select the **Run Once Duration Override Operator** and click **Install**.
- d. On the **Install Operator** page:
  - i. The **Update channel** is set to **stable**, which installs the latest stable release of the Run Once Duration Override Operator.
  - ii. Select **A specific namespace on the cluster**
  - iii. Choose **openshift-run-once-duration-override-operator** from the dropdown menu under **Installed namespace**.
  - iv. Select an **Update approval** strategy.
    - The **Automatic** strategy allows Operator Lifecycle Manager (OLM) to automatically update the Operator when a new version is available.
    - The **Manual** strategy requires a user with appropriate credentials to approve the Operator update.
  - v. Click **Install**.
4. Create a **RunOnceDurationOverride** instance.
  - a. From the **Operators → Installed Operators** page, click **Run Once Duration Override Operator**.
  - b. Select the **Run Once Duration Override** tab and click **Create RunOnceDurationOverride**.
  - c. Edit the settings as necessary.  
Under the **runOnceDurationOverride** section, you can update the **spec.activeDeadlineSeconds** value, if required. The predefined value is **3600** seconds, or 1 hour.
  - d. Click **Create**.

## Verification

1. Log in to the OpenShift CLI.
2. Verify all pods are created and running properly.

```
$ oc get pods -n openshift-run-once-duration-override-operator
```

### Example output

```
NAME                                READY STATUS RESTARTS AGE
run-once-duration-override-operator-7b88c676f6-lcxgc 1/1 Running 0 7m46s
runoncedurationoverride-62blp        1/1 Running 0 41s
runoncedurationoverride-h8h8b        1/1 Running 0 41s
runoncedurationoverride-tdsqk        1/1 Running 0 41s
```

### 2.12.3.2. Enabling the run-once duration override on a namespace

To apply the run-once duration override from the Run Once Duration Override Operator to run-once pods, you must enable it on each applicable namespace.

## Prerequisites

- The Run Once Duration Override Operator is installed.

## Procedure

1. Log in to the OpenShift CLI.
2. Add the label to enable the run-once duration override to your namespace:

```
$ oc label namespace <namespace> \ 1
  runoncedurationoverrides.admission.runoncedurationoverride.openshift.io/enabled=true
```

- 1** Specify the namespace to enable the run-once duration override on.

After you enable the run-once duration override on this namespace, future run-once pods that are created in this namespace will have their **activeDeadlineSeconds** field set to the override value from the Run Once Duration Override Operator. Existing pods in this namespace will also have their **activeDeadlineSeconds** value set when they are updated next.

## Verification

1. Create a test run-once pod in the namespace that you enabled the run-once duration override on:

```
apiVersion: v1
kind: Pod
metadata:
  name: example
  namespace: <namespace> 1
spec:
  restartPolicy: Never 2
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: busybox
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
    image: busybox:1.25
    command:
      - /bin/sh
      - -ec
      - |
        while sleep 5; do date; done
```

- 1** Replace **<namespace>** with the name of your namespace.
- 2** The **restartPolicy** must be **Never** or **OnFailure** to be a run-once pod.

2. Verify that the pod has its **activeDeadlineSeconds** field set:

```
$ oc get pods -n <namespace> -o yaml | grep activeDeadlineSeconds
```

#### Example output

```
activeDeadlineSeconds: 3600
```

### 2.12.3.3. Updating the run-once active deadline override value

You can customize the override value that the Run Once Duration Override Operator applies to run-once pods. The predefined value is **3600** seconds, or 1 hour.

#### Prerequisites

- You have access to the cluster with **cluster-admin** privileges.
- You have installed the Run Once Duration Override Operator.

#### Procedure

1. Log in to the OpenShift CLI.
2. Edit the **RunOnceDurationOverride** resource:

```
$ oc edit runoncedurationoverride cluster
```

3. Update the **activeDeadlineSeconds** field:

```
apiVersion: operator.openshift.io/v1
kind: RunOnceDurationOverride
metadata:
# ...
spec:
  runOnceDurationOverride:
    spec:
      activeDeadlineSeconds: 1800 1
# ...
```

- 1** Set the **activeDeadlineSeconds** field to the desired value, in seconds.

4. Save the file to apply the changes.

Any future run-once pods created in namespaces where the run-once duration override is enabled will have their **activeDeadlineSeconds** field set to this new value. Existing run-once pods in these namespaces will receive this new value when they are updated.

### 2.12.4. Uninstalling the Run Once Duration Override Operator

You can remove the Run Once Duration Override Operator from OpenShift Container Platform by uninstalling the Operator and removing its related resources.



## IMPORTANT

The Run Once Duration Override Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.



### 2.12.4.1. Uninstalling the Run Once Duration Override Operator

You can use the web console to uninstall the Run Once Duration Override Operator. Uninstalling the Run Once Duration Override Operator does not unset the **activeDeadlineSeconds** field for run-once pods, but it will no longer apply the override value to future run-once pods.

#### Prerequisites

- You have access to the cluster with **cluster-admin** privileges.
- You have access to the OpenShift Container Platform web console.
- You have installed the Run Once Duration Override Operator.

#### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Navigate to **Operators** → **Installed Operators**.
3. Select **openshift-run-once-duration-override-operator** from the **Project** dropdown list.
4. Delete the **RunOnceDurationOverride** instance.
  - a. Click **Run Once Duration Override Operator** and select the **Run Once Duration Override** tab.
  - b. Click the Options menu  next to the **cluster** entry and select **Delete RunOnceDurationOverride**.
  - c. In the confirmation dialog, click **Delete**.
5. Uninstall the Run Once Duration Override Operator Operator.
  - a. Navigate to **Operators** → **Installed Operators**.
  - b. Click the Options menu  next to the **Run Once Duration Override Operator** entry and click **Uninstall Operator**.
  - c. In the confirmation dialog, click **Uninstall**.



### 2.12.4.2. Uninstalling Run Once Duration Override Operator resources

Optionally, after uninstalling the Run Once Duration Override Operator, you can remove its related resources from your cluster.

#### Prerequisites

- You have access to the cluster with **cluster-admin** privileges.
- You have access to the OpenShift Container Platform web console.
- You have uninstalled the Run Once Duration Override Operator.

## Procedure

1. Log in to the OpenShift Container Platform web console.
2. Remove CRDs that were created when the Run Once Duration Override Operator was installed:
  - a. Navigate to **Administration** → **CustomResourceDefinitions**.
  - b. Enter **RunOnceDurationOverride** in the **Name** field to filter the CRDs.
  - c. Click the Options menu  next to the **RunOnceDurationOverride** CRD and select **Delete CustomResourceDefinition**.
  - d. In the confirmation dialog, click **Delete**.
3. Delete the **openshift-run-once-duration-override-operator** namespace.
  - a. Navigate to **Administration** → **Namespaces**.
  - b. Enter **openshift-run-once-duration-override-operator** into the filter box.
  - c. Click the Options menu  next to the **openshift-run-once-duration-override-operator** entry and select **Delete Namespace**.
  - d. In the confirmation dialog, enter **openshift-run-once-duration-override-operator** and click **Delete**.
4. Remove the run-once duration override label from the namespaces that it was enabled on.
  - a. Navigate to **Administration** → **Namespaces**.
  - b. Select your namespace.
  - c. Click **Edit** next to the **Labels** field.
  - d. Remove the **runoncedurationoverrides.admission.runoncedurationoverride.openshift.io/enabled=true** label and click **Save**.

## 2.13. RUNNING PODS IN LINUX USER NAMESPACES

Linux user namespaces allow administrators to isolate the container user and group identifiers (UIDs and GIDs) so that a container can have a different set of permissions in the user namespace than on the host system where it is running. This allows containers to run processes with full privileges inside the user namespace, but the processes can be unprivileged for operations on the host machine.

By default, a container runs in the host system's root user namespace. Running a container in the host user namespace can be useful when the container needs a feature that is available only in that user



namespace. However, it introduces security concerns, such as the possibility of container breakouts, in which a process inside a container breaks out onto the host where the process can access or modify files on the host or in other containers.

Running containers in individual user namespaces can mitigate container breakouts and several other vulnerabilities that a compromised container can pose to other pods and the node itself.

You can configure Linux user namespace use by setting the **hostUsers** parameter to **false** in the pod spec, as shown in the following procedure.



### IMPORTANT

Support for Linux user namespaces 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](#).

## 2.13.1. Configuring Linux user namespace support

### Prerequisites

- You enabled the required Technology Preview features for your cluster by editing the **FeatureGate** CR named **cluster**:

```
$ oc edit featuregate cluster
```

### Example FeatureGate CR

```
apiVersion: config.openshift.io/v1
kind: FeatureGate
metadata:
  name: cluster
spec:
  featureSet: TechPreviewNoUpgrade 1
```

- 1** Enables the required **UserNamespacesSupport** and **ProcMountType** features.



### WARNING

Enabling the **TechPreviewNoUpgrade** feature set on your cluster cannot be undone and prevents minor version updates. This feature set allows you to enable these Technology Preview features on test clusters, where you can fully test them. Do not enable this feature set on production clusters.

After you save the changes, new machine configs are created, the machine config pools are updated, and scheduling on each node is disabled while the change is being applied.

- You enabled the crun container runtime on the worker nodes. crun is currently the only released OCI runtime with support for user namespaces.

```
apiVersion: machineconfiguration.openshift.io/v1
kind: ContainerRuntimeConfig
metadata:
  name: enable-crun-worker
spec:
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" 1
  containerRuntimeConfig:
    defaultRuntime: crun 2
```

**1** Specifies the machine config pool label.

**2** Specifies the container runtime to deploy.

## Procedure

- Edit the default user ID (UID) and group ID (GID) range of the OpenShift Container Platform namespace where your pod is deployed by running the following command:

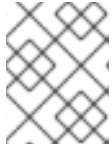
```
$ oc edit ns/<namespace_name>
```

### Example namespace

```
apiVersion: v1
kind: Namespace
metadata:
  annotations:
    openshift.io/description: ""
    openshift.io/display-name: ""
    openshift.io/requester: system:admin
    openshift.io/sa.scc.mcs: s0:c27,c24
    openshift.io/sa.scc.supplemental-groups: 1024/10000 1
    openshift.io/sa.scc.uid-range: 1024/10000 2
# ...
name: userns
# ...
```

**1** Edit the default GID to match the value you specified in the pod spec. The range for a Linux user namespace must be lower than 65,535. The default is **1000000000/10000**.

**2** Edit the default UID to match the value you specified in the pod spec. The range for a Linux user namespace must be lower than 65,535. The default is **1000000000/10000**.

**NOTE**

The range 1024/10000 means 10,000 values starting with ID 1024, so it specifies the range of IDs from 1024 to 11,023.

2. Enable the use of Linux user namespaces by creating a pod configured to run with a **restricted** profile and with the **hostUsers** parameter set to **false**.
  - a. Create a YAML file similar to the following:

**Example pod specification**

```

apiVersion: v1
kind: Pod
metadata:
  name: usersns-pod

# ...

spec:
  containers:
  - name: usersns-container
    image: registry.access.redhat.com/ubi9
    command: ["sleep", "1000"]
    securityContext:
      capabilities:
        drop: ["ALL"]
      allowPrivilegeEscalation: false 1
      runAsNonRoot: true 2
      seccompProfile:
        type: RuntimeDefault
      runAsUser: 1024 3
      runAsGroup: 1024 4
    hostUsers: false 5

# ...

```

- 1 Specifies that a pod cannot request privilege escalation. This is required for the **restricted-v2** security context constraints (SCC).
- 2 Specifies that the container will run with a user with any UID other than 0.
- 3 Specifies the UID the container is run with.
- 4 Specifies which primary GID the containers is run with.
- 5 Requests that the pod is to be run in a user namespace. If **true**, the pod runs in the host user namespace. If **false**, the pod runs in a new user namespace that is created for the pod. The default is **true**.

- b. Create the pod by running the following command:

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

## Verification

1. Check the pod user and group IDs being used in the pod container you created. The pod is inside the Linux user namespace.

- a. Start a shell session with the container in your pod:

```
$ oc rsh -c <container_name> pod/<pod_name>
```

### Example command

```
$ oc rsh -c userns-container_name pod/userns-pod
```

- b. Display the user and group IDs being used inside the container:

```
sh-5.1$ id
```

### Example output

```
uid=1024(1024) gid=1024(1024) groups=1024(1024)
```

- c. Display the user ID being used in the container user namespace:

```
sh-5.1$ lsns -t user
```

### Example output

```

      NS TYPE  NPROCS  PID  USER  COMMAND
4026532447 user    3   1 1024 /usr/bin/coreutils --coreutils-prog-shebang=sleep
/usr/bin/sleep 1000 1
```

- 1** The UID for the process is **1024**, the same as you set in the pod spec.

2. Check the pod user ID being used on the node where the pod was created. The node is outside of the Linux user namespace. This user ID should be different from the UID being used in the container.

- a. Start a debug session for that node:

```
$ oc debug node/ci-ln-z5vppzb-72292-8zp2b-worker-c-q8sh9
```

### Example command

```
$ oc debug node/ci-ln-z5vppzb-72292-8zp2b-worker-c-q8sh9
```

- b. Set **/host** as the root directory within the debug shell:

```
sh-5.1# chroot /host
```

- c. Display the user ID being used in the node user namespace:

```
sh-5.1# lsns -t user
```

### Example command

```
      NS TYPE NPROCS  PID USER   COMMAND
4026531837 user   233   1 root   /usr/lib/systemd/systemd --switched-root --system -
-derialize 28
4026532447 user     1 4767 2908816384 /usr/bin/coreutils --coreutils-prog-
shebang=sleep /usr/bin/sleep 1000 1
```

- 1** The UID for the process is **2908816384**, which is different from what you set in the pod spec.

## CHAPTER 3. AUTOMATICALLY SCALING PODS WITH THE CUSTOM METRICS AUTOSCALER OPERATOR

### 3.1. RELEASE NOTES

#### 3.1.1. Custom Metrics Autoscaler Operator release notes

The release notes for the Custom Metrics Autoscaler Operator for Red Hat OpenShift describe new features and enhancements, deprecated features, and known issues.

The Custom Metrics Autoscaler Operator uses the Kubernetes-based Event Driven Autoscaler (KEDA) and is built on top of the OpenShift Container Platform horizontal pod autoscaler (HPA).



#### NOTE

The Custom Metrics Autoscaler Operator for Red Hat OpenShift is provided as an installable component, with a distinct release cycle from the core OpenShift Container Platform. The [Red Hat OpenShift Container Platform Life Cycle Policy](#) outlines release compatibility.

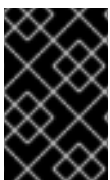
##### 3.1.1.1. Supported versions

The following table defines the Custom Metrics Autoscaler Operator versions for each OpenShift Container Platform version.

Version	OpenShift Container Platform version	General availability
2.14.1	4.16	General availability
2.14.1	4.15	General availability
2.14.1	4.14	General availability
2.14.1	4.13	General availability
2.14.1	4.12	General availability

##### 3.1.1.2. Custom Metrics Autoscaler Operator 2.14.1-467 release notes

This release of the Custom Metrics Autoscaler Operator 2.14.1-467 provides a CVE and a bug fix for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHSA-2024:7348](#).



#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of Kubernetes-based Event Driven Autoscaler (KEDA).

### 3.1.1.2.1. Bug fixes

- Previously, the root file system of the Custom Metrics Autoscaler Operator pod was writable, which is unnecessary and could present security issues. This update makes the pod root file system read-only, which addresses the potential security issue. ([OCPBUGS-37989](#))

## 3.1.2. Release notes for past releases of the Custom Metrics Autoscaler Operator

The following release notes are for previous versions of the Custom Metrics Autoscaler Operator.

For the current version, see [Custom Metrics Autoscaler Operator release notes](#).

### 3.1.2.1. Custom Metrics Autoscaler Operator 2.14.1-454 release notes

This release of the Custom Metrics Autoscaler Operator 2.14.1-454 provides a CVE, a new feature, and bug fixes for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHBA-2024:5865](#).



#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of Kubernetes-based Event Driven Autoscaler (KEDA).

### 3.1.2.1.1. New features and enhancements

#### 3.1.2.1.1.1. Support for the Cron trigger with the Custom Metrics Autoscaler Operator

The Custom Metrics Autoscaler Operator can now use the Cron trigger to scale pods based on an hourly schedule. When your specified time frame starts, the Custom Metrics Autoscaler Operator scales pods to your desired amount. When the time frame ends, the Operator scales back down to the previous level.

For more information, see [Understanding the Cron trigger](#).

### 3.1.2.1.2. Bug fixes

- Previously, if you made changes to audit configuration parameters in the **KedaController** custom resource, the **keda-metrics-server-audit-policy** config map would not get updated. As a consequence, you could not change the audit configuration parameters after the initial deployment of the Custom Metrics Autoscaler. With this fix, changes to the audit configuration now render properly in the config map, allowing you to change the audit configuration any time after installation. ([OCPBUGS-32521](#))

### 3.1.2.2. Custom Metrics Autoscaler Operator 2.13.1 release notes

This release of the Custom Metrics Autoscaler Operator 2.13.1-421 provides a new feature and a bug fix for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHBA-2024:4837](#).



## IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of Kubernetes-based Event Driven Autoscaler (KEDA).

### 3.1.2.2.1. New features and enhancements

#### 3.1.2.2.1.1. Support for custom certificates with the Custom Metrics Autoscaler Operator

The Custom Metrics Autoscaler Operator can now use custom service CA certificates to connect securely to TLS-enabled metrics sources, such as an external Kafka cluster or an external Prometheus service. By default, the Operator uses automatically-generated service certificates to connect to on-cluster services only. There is a new field in the **KedaController** object that allows you to load custom server CA certificates for connecting to external services by using config maps.

For more information, see [Custom CA certificates for the Custom Metrics Autoscaler](#) .

#### 3.1.2.2.2. Bug fixes

- Previously, the **custom-metrics-autoscaler** and **custom-metrics-autoscaler-adapter** images were missing time zone information. As a consequence, scaled objects with **cron** triggers failed to work because the controllers were unable to find time zone information. With this fix, the image builds are updated to include time zone information. As a result, scaled objects containing **cron** triggers now function properly. Scaled objects containing **cron** triggers are currently not supported for the custom metrics autoscaler. ([OCPBUGS-34018](#))

### 3.1.2.3. Custom Metrics Autoscaler Operator 2.12.1-394 release notes

This release of the Custom Metrics Autoscaler Operator 2.12.1-394 provides a bug fix for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHSA-2024:2901](#).



## IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of Kubernetes-based Event Driven Autoscaler (KEDA).

#### 3.1.2.3.1. Bug fixes

- Previously, the **protojson.Unmarshal** function entered into an infinite loop when unmarshaling certain forms of invalid JSON. This condition could occur when unmarshaling into a message that contains a **google.protobuf.Any** value or when the **UnmarshalOptions.DiscardUnknown** option is set. This release fixes this issue. ([OCPBUGS-30305](#))
- Previously, when parsing a multipart form, either explicitly with the **Request.ParseMultipartForm** method or implicitly with the **Request.FormValue**, **Request.PostFormValue**, or **Request.FormFile** method, the limits on the total size of the parsed form were not applied to the memory consumed. This could cause memory exhaustion. With this fix, the parsing process now correctly limits the maximum size of form lines while reading a single form line. ([OCPBUGS-30360](#))
- Previously, when following an HTTP redirect to a domain that is not on a matching subdomain or on an exact match of the initial domain, an HTTP client would not forward sensitive headers,



such as **Authorization** or **Cookie**. For example, a redirect from **example.com** to **www.example.com** would forward the **Authorization** header, but a redirect to **www.example.org** would not forward the header. This release fixes this issue. ( [OCPBUGS-30365](#) )

- Previously, verifying a certificate chain that contains a certificate with an unknown public key algorithm caused the certificate verification process to panic. This condition affected all crypto and Transport Layer Security (TLS) clients and servers that set the **Config.ClientAuth** parameter to the **VerifyClientCertIfGiven** or **RequireAndVerifyClientCert** value. The default behavior is for TLS servers to not verify client certificates. This release fixes this issue. ( [OCPBUGS-30370](#) )
- Previously, if errors returned from the **MarshalJSON** method contained user-controlled data, an attacker could have used the data to break the contextual auto-escaping behavior of the HTML template package. This condition would allow for subsequent actions to inject unexpected content into the templates. This release fixes this issue. ( [OCPBUGS-30397](#) )
- Previously, the **net/http** and **golang.org/x/net/http2** Go packages did not limit the number of **CONTINUATION** frames for an HTTP/2 request. This condition could result in excessive CPU consumption. This release fixes this issue. ( [OCPBUGS-30894](#) )

#### 3.1.2.4. Custom Metrics Autoscaler Operator 2.12.1-384 release notes

This release of the Custom Metrics Autoscaler Operator 2.12.1-384 provides a bug fix for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHBA-2024:2043](#).



#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of KEDA.

##### 3.1.2.4.1. Bug fixes

- Previously, the **custom-metrics-autoscaler** and **custom-metrics-autoscaler-adapter** images were missing time zone information. As a consequence, scaled objects with **cron** triggers failed to work because the controllers were unable to find time zone information. With this fix, the image builds are updated to include time zone information. As a result, scaled objects containing **cron** triggers now function properly. ( [OCPBUGS-32395](#) )

#### 3.1.2.5. Custom Metrics Autoscaler Operator 2.12.1-376 release notes

This release of the Custom Metrics Autoscaler Operator 2.12.1-376 provides security updates and bug fixes for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHSA-2024:1812](#).



#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of KEDA.

##### 3.1.2.5.1. Bug fixes

- Previously, if invalid values such as nonexistent namespaces were specified in scaled object metadata, the underlying scaler clients would not free, or close, their client descriptors, resulting in a slow memory leak. This fix properly closes the underlying client descriptors when there are errors, preventing memory from leaking. ([OCPBUGS-30145](#))
- Previously the **ServiceMonitor** custom resource (CR) for the **keda-metrics-apiserver** pod was not functioning, because the CR referenced an incorrect metrics port name of **http**. This fix corrects the **ServiceMonitor** CR to reference the proper port name of **metrics**. As a result, the Service Monitor functions properly. ([OCPBUGS-25806](#))

### 3.1.2.6. Custom Metrics Autoscaler Operator 2.11.2-322 release notes

This release of the Custom Metrics Autoscaler Operator 2.11.2-322 provides security updates and bug fixes for running the Operator in an OpenShift Container Platform cluster. The following advisory is available for the [RHSA-2023:6144](#).



#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of KEDA.

#### 3.1.2.6.1. Bug fixes

- Because the Custom Metrics Autoscaler Operator version 3.11.2-311 was released without a required volume mount in the Operator deployment, the Custom Metrics Autoscaler Operator pod would restart every 15 minutes. This fix adds the required volume mount to the Operator deployment. As a result, the Operator no longer restarts every 15 minutes. ([OCPBUGS-22361](#))

### 3.1.2.7. Custom Metrics Autoscaler Operator 2.11.2-311 release notes

This release of the Custom Metrics Autoscaler Operator 2.11.2-311 provides new features and bug fixes for running the Operator in an OpenShift Container Platform cluster. The components of the Custom Metrics Autoscaler Operator 2.11.2-311 were released in [RHBA-2023:5981](#).



#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of KEDA.

#### 3.1.2.7.1. New features and enhancements

##### 3.1.2.7.1.1. Red Hat OpenShift Service on AWS (ROSA) and OpenShift Dedicated are now supported

The Custom Metrics Autoscaler Operator 2.11.2-311 can be installed on OpenShift ROSA and OpenShift Dedicated managed clusters. Previous versions of the Custom Metrics Autoscaler Operator could be installed only in the **openshift-keda** namespace. This prevented the Operator from being installed on OpenShift ROSA and OpenShift Dedicated clusters. This version of Custom Metrics Autoscaler allows installation to other namespaces such as **openshift-operators** or **keda**, enabling installation into ROSA and Dedicated clusters.

#### 3.1.2.7.2. Bug fixes

- Previously, if the Custom Metrics Autoscaler Operator was installed and configured, but not in use, the OpenShift CLI reported the **couldn't get resource list for external.metrics.k8s.io/v1beta1: Got empty response for: external.metrics.k8s.io/v1beta1** error after any **oc** command was entered. The message, although harmless, could have caused confusion. With this fix, the **Got empty response for: external.metrics...** error no longer appears inappropriately. ([OCPBUGS-15779](#))
- Previously, any annotation or label change to objects managed by the Custom Metrics Autoscaler were reverted by Custom Metrics Autoscaler Operator any time the Keda Controller was modified, for example after a configuration change. This caused continuous changing of labels in your objects. The Custom Metrics Autoscaler now uses its own annotation to manage labels and annotations, and annotation or label are no longer inappropriately reverted. ([OCPBUGS-15590](#))

### 3.1.2.8. Custom Metrics Autoscaler Operator 2.10.1-267 release notes

This release of the Custom Metrics Autoscaler Operator 2.10.1-267 provides new features and bug fixes for running the Operator in an OpenShift Container Platform cluster. The components of the Custom Metrics Autoscaler Operator 2.10.1-267 were released in [RHBA-2023:4089](#).



#### IMPORTANT

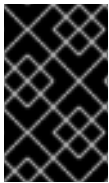
Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of KEDA.

#### 3.1.2.8.1. Bug fixes

- Previously, the **custom-metrics-autoscaler** and **custom-metrics-autoscaler-adapter** images did not contain time zone information. Because of this, scaled objects with cron triggers failed to work because the controllers were unable to find time zone information. With this fix, the image builds now include time zone information. As a result, scaled objects containing cron triggers now function properly. ([OCPBUGS-15264](#))
- Previously, the Custom Metrics Autoscaler Operator would attempt to take ownership of all managed objects, including objects in other namespaces and cluster-scoped objects. Because of this, the Custom Metrics Autoscaler Operator was unable to create the role binding for reading the credentials necessary to be an API server. This caused errors in the **kube-system** namespace. With this fix, the Custom Metrics Autoscaler Operator skips adding the **ownerReference** field to any object in another namespace or any cluster-scoped object. As a result, the role binding is now created without any errors. ([OCPBUGS-15038](#))
- Previously, the Custom Metrics Autoscaler Operator added an **ownerReferences** field to the **openshift-keda** namespace. While this did not cause functionality problems, the presence of this field could have caused confusion for cluster administrators. With this fix, the Custom Metrics Autoscaler Operator does not add the **ownerReference** field to the **openshift-keda** namespace. As a result, the **openshift-keda** namespace no longer has a superfluous **ownerReference** field. ([OCPBUGS-15293](#))
- Previously, if you used a Prometheus trigger configured with authentication method other than pod identity, and the **podidentity** parameter was set to **none**, the trigger would fail to scale. With this fix, the Custom Metrics Autoscaler for OpenShift now properly handles the **none** pod identity provider type. As a result, a Prometheus trigger configured with authentication method other than pod identity, and the **podidentity** parameter sset to **none** now properly scales. ([OCPBUGS-15274](#))

### 3.1.2.9. Custom Metrics Autoscaler Operator 2.10.1 release notes

This release of the Custom Metrics Autoscaler Operator 2.10.1 provides new features and bug fixes for running the Operator in an OpenShift Container Platform cluster. The components of the Custom Metrics Autoscaler Operator 2.10.1 were released in [RHEA-2023:3199](#).



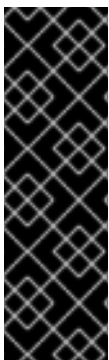
#### IMPORTANT

Before installing this version of the Custom Metrics Autoscaler Operator, remove any previously installed Technology Preview versions or the community-supported version of KEDA.

#### 3.1.2.9.1. New features and enhancements

##### 3.1.2.9.1.1. Custom Metrics Autoscaler Operator general availability

The Custom Metrics Autoscaler Operator is now generally available as of Custom Metrics Autoscaler Operator version 2.10.1.



#### IMPORTANT

Scaling by using a scaled job 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](#).

##### 3.1.2.9.1.2. Performance metrics

You can now use the Prometheus Query Language (PromQL) to query metrics on the Custom Metrics Autoscaler Operator.

##### 3.1.2.9.1.3. Pausing the custom metrics autoscaling for scaled objects

You can now pause the autoscaling of a scaled object, as needed, and resume autoscaling when ready.

##### 3.1.2.9.1.4. Replica fall back for scaled objects

You can now specify the number of replicas to fall back to if a scaled object fails to get metrics from the source.

##### 3.1.2.9.1.5. Customizable HPA naming for scaled objects

You can now specify a custom name for the horizontal pod autoscaler in scaled objects.

##### 3.1.2.9.1.6. Activation and scaling thresholds

Because the horizontal pod autoscaler (HPA) cannot scale to or from 0 replicas, the Custom Metrics Autoscaler Operator does that scaling, after which the HPA performs the scaling. You can now specify when the HPA takes over autoscaling, based on the number of replicas. This allows for more flexibility with your scaling policies.

### 3.1.2.10. Custom Metrics Autoscaler Operator 2.8.2-174 release notes

This release of the Custom Metrics Autoscaler Operator 2.8.2-174 provides new features and bug fixes for running the Operator in an OpenShift Container Platform cluster. The components of the Custom Metrics Autoscaler Operator 2.8.2-174 were released in [RHEA-2023:1683](#).



#### IMPORTANT

The Custom Metrics Autoscaler Operator version 2.8.2-174 is a [Technology Preview](#) feature.

#### 3.1.2.10.1. New features and enhancements

##### 3.1.2.10.1.1. Operator upgrade support

You can now upgrade from a prior version of the Custom Metrics Autoscaler Operator. See "Changing the update channel for an Operator" in the "Additional resources" for information on upgrading an Operator.

##### 3.1.2.10.1.2. must-gather support

You can now collect data about the Custom Metrics Autoscaler Operator and its components by using the OpenShift Container Platform **must-gather** tool. Currently, the process for using the **must-gather** tool with the Custom Metrics Autoscaler is different than for other operators. See "Gathering debugging data in the "Additional resources" for more information.

### 3.1.2.11. Custom Metrics Autoscaler Operator 2.8.2 release notes

This release of the Custom Metrics Autoscaler Operator 2.8.2 provides new features and bug fixes for running the Operator in an OpenShift Container Platform cluster. The components of the Custom Metrics Autoscaler Operator 2.8.2 were released in [RHSA-2023:1042](#).



#### IMPORTANT

The Custom Metrics Autoscaler Operator version 2.8.2 is a [Technology Preview](#) feature.

#### 3.1.2.11.1. New features and enhancements

##### 3.1.2.11.1.1. Audit Logging

You can now gather and view audit logs for the Custom Metrics Autoscaler Operator and its associated components. Audit logs are security-relevant chronological sets of records that document the sequence of activities that have affected the system by individual users, administrators, or other components of the system.

##### 3.1.2.11.1.2. Scale applications based on Apache Kafka metrics

You can now use the KEDA Apache kafka trigger/scaler to scale deployments based on an Apache Kafka topic.

##### 3.1.2.11.1.3. Scale applications based on CPU metrics

You can now use the KEDA CPU trigger/scaler to scale deployments based on CPU metrics.

#### 3.1.2.11.1.4. Scale applications based on memory metrics

You can now use the KEDA memory trigger/scaler to scale deployments based on memory metrics.

## 3.2. CUSTOM METRICS AUTOSCALER OPERATOR OVERVIEW

As a developer, you can use Custom Metrics Autoscaler Operator for Red Hat OpenShift to specify how OpenShift Container Platform should automatically increase or decrease the number of pods for a deployment, stateful set, custom resource, or job based on custom metrics that are not based only on CPU or memory.

The Custom Metrics Autoscaler Operator is an optional Operator, based on the Kubernetes Event Driven Autoscaler (KEDA), that allows workloads to be scaled using additional metrics sources other than pod metrics.

The custom metrics autoscaler currently supports only the Prometheus, CPU, memory, and Apache Kafka metrics.

The Custom Metrics Autoscaler Operator scales your pods up and down based on custom, external metrics from specific applications. Your other applications continue to use other scaling methods. You configure *triggers*, also known as scalers, which are the source of events and metrics that the custom metrics autoscaler uses to determine how to scale. The custom metrics autoscaler uses a metrics API to convert the external metrics to a form that OpenShift Container Platform can use. The custom metrics autoscaler creates a horizontal pod autoscaler (HPA) that performs the actual scaling.

To use the custom metrics autoscaler, you create a **ScaledObject** or **ScaledJob** object for a workload, which is a custom resource (CR) that defines the scaling metadata. You specify the deployment or job to scale, the source of the metrics to scale on (trigger), and other parameters such as the minimum and maximum replica counts allowed.



### NOTE

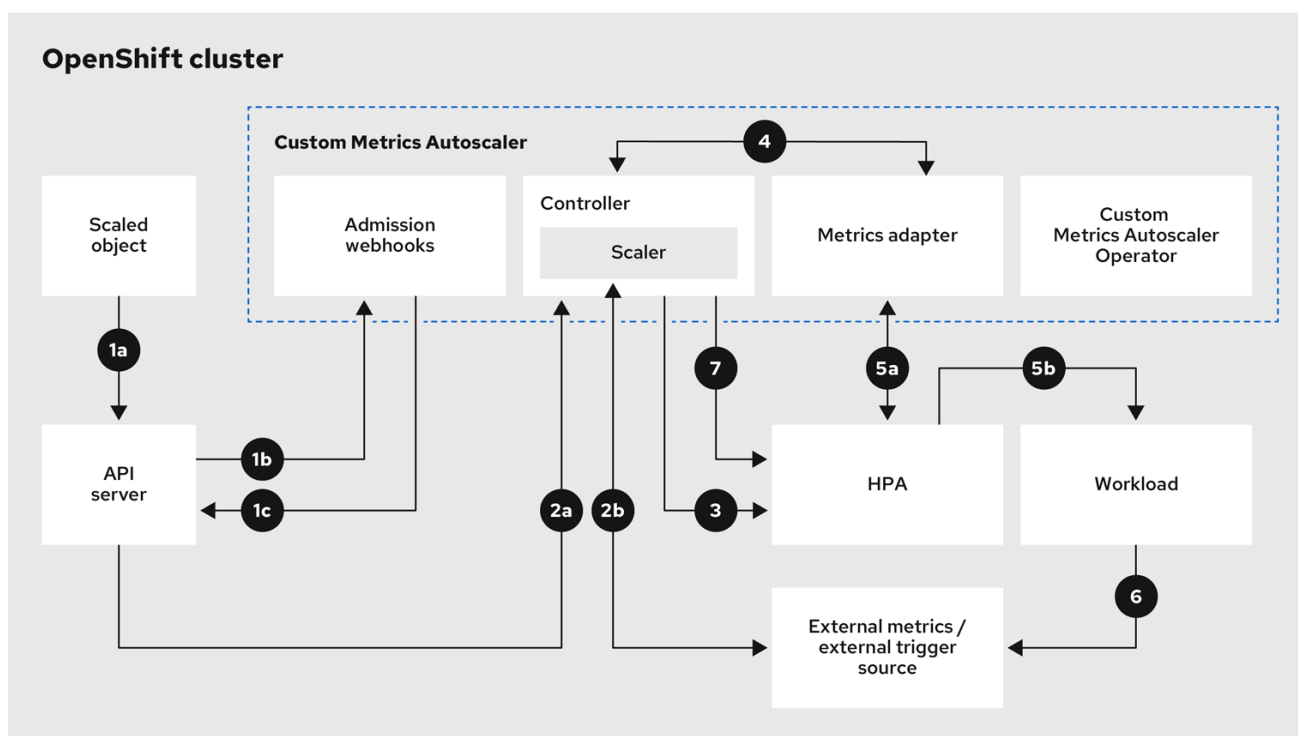
You can create only one scaled object or scaled job for each workload that you want to scale. Also, you cannot use a scaled object or scaled job and the horizontal pod autoscaler (HPA) on the same workload.

The custom metrics autoscaler, unlike the HPA, can scale to zero. If you set the **minReplicaCount** value in the custom metrics autoscaler CR to **0**, the custom metrics autoscaler scales the workload down from 1 to 0 replicas to or up from 0 replicas to 1. This is known as the *activation phase*. After scaling up to 1 replica, the HPA takes control of the scaling. This is known as the *scaling phase*.

Some triggers allow you to change the number of replicas that are scaled by the cluster metrics autoscaler. In all cases, the parameter to configure the activation phase always uses the same phrase, prefixed with *activation*. For example, if the **threshold** parameter configures scaling, **activationThreshold** would configure activation. Configuring the activation and scaling phases allows you more flexibility with your scaling policies. For example, you can configure a higher activation phase to prevent scaling up or down if the metric is particularly low.

The activation value has more priority than the scaling value in case of different decisions for each. For example, if the **threshold** is set to **10**, and the **activationThreshold** is **50**, if the metric reports **40**, the scaler is not active and the pods are scaled to zero even if the HPA requires 4 instances.

Figure 3.1. Custom metrics autoscaler workflow



565\_OpenShift\_0224

1. You create or modify a scaled object custom resource for a workload on a cluster. The object contains the scaling configuration for that workload. Prior to accepting the new object, the OpenShift API server sends it to the custom metrics autoscaler admission webhooks process to ensure that the object is valid. If validation succeeds, the API server persists the object.
2. The custom metrics autoscaler controller watches for new or modified scaled objects. When the OpenShift API server notifies the controller of a change, the controller monitors any external trigger sources, also known as data sources, that are specified in the object for changes to the metrics data. One or more scalers request scaling data from the external trigger source. For example, for a Kafka trigger type, the controller uses the Kafka scaler to communicate with a Kafka instance to obtain the data requested by the trigger.
3. The controller creates a horizontal pod autoscaler object for the scaled object. As a result, the Horizontal Pod Autoscaler (HPA) Operator starts monitoring the scaling data associated with the trigger. The HPA requests scaling data from the cluster OpenShift API server endpoint.
4. The OpenShift API server endpoint is served by the custom metrics autoscaler metrics adapter. When the metrics adapter receives a request for custom metrics, it uses a GRPC connection to the controller to request it for the most recent trigger data received from the scaler.
5. The HPA makes scaling decisions based upon the data received from the metrics adapter and scales the workload up or down by increasing or decreasing the replicas.
6. As it operates, a workload can affect the scaling metrics. For example, if a workload is scaled up to handle work in a Kafka queue, the queue size decreases after the workload processes all the work. As a result, the workload is scaled down.
7. If the metrics are in a range specified by the **minReplicaCount** value, the custom metrics autoscaler controller disables all scaling, and leaves the replica count at a fixed level. If the metrics exceed that range, the custom metrics autoscaler controller enables scaling and allows the HPA to scale the workload. While scaling is disabled, the HPA does not take any action.



### 3.2.1. Custom CA certificates for the Custom Metrics Autoscaler

By default, the Custom Metrics Autoscaler Operator uses automatically-generated service CA certificates to connect to on-cluster services.

If you want to use off-cluster services that require custom CA certificates, you can add the required certificates to a config map. Then, add the config map to the **KedaController** custom resource as described in [Installing the custom metrics autoscaler](#). The Operator loads those certificates on start-up and registers them as trusted by the Operator.

The config maps can contain one or more certificate files that contain one or more PEM-encoded CA certificates. Or, you can use separate config maps for each certificate file.



#### NOTE

If you later update the config map to add additional certificates, you must restart the **keda-operator-\*** pod for the changes to take effect.

## 3.3. INSTALLING THE CUSTOM METRICS AUTOSCALER

You can use the OpenShift Container Platform web console to install the Custom Metrics Autoscaler Operator.

The installation creates the following five CRDs:

- **ClusterTriggerAuthentication**
- **KedaController**
- **ScaledJob**
- **ScaledObject**
- **TriggerAuthentication**

### 3.3.1. Installing the custom metrics autoscaler

You can use the following procedure to install the Custom Metrics Autoscaler Operator.

#### Prerequisites

- Remove any previously-installed Technology Preview versions of the Custom Metrics Autoscaler Operator.
- Remove any versions of the community-based KEDA.  
Also, remove the KEDA 1.x custom resource definitions by running the following commands:

```
$ oc delete crd scaledobjects.keda.k8s.io
```

```
$ oc delete crd triggerauthentications.keda.k8s.io
```

- Optional: If you need the Custom Metrics Autoscaler Operator to connect to off-cluster services, such as an external Kafka cluster or an external Prometheus service, put any required service CA certificates into a config map. The config map must exist in the same namespace



where the Operator is installed. For example:

```
$ oc create configmap -n openshift-keda thanos-cert --from-file=ca-cert.pem
```

## Procedure

1. In the OpenShift Container Platform web console, click **Operators** → **OperatorHub**.
2. Choose **Custom Metrics Autoscaler** from the list of available Operators, and click **Install**.
3. On the **Install Operator** page, ensure that the **All namespaces on the cluster (default)** option is selected for **Installation Mode**. This installs the Operator in all namespaces.
4. Ensure that the **openshift-keda** namespace is selected for **Installed Namespace**. OpenShift Container Platform creates the namespace, if not present in your cluster.
5. Click **Install**.
6. Verify the installation by listing the Custom Metrics Autoscaler Operator components:
  - a. Navigate to **Workloads** → **Pods**.
  - b. Select the **openshift-keda** project from the drop-down menu and verify that the **custom-metrics-autoscaler-operator-\*** pod is running.
  - c. Navigate to **Workloads** → **Deployments** to verify that the **custom-metrics-autoscaler-operator** deployment is running.
7. Optional: Verify the installation in the OpenShift CLI using the following commands:

```
$ oc get all -n openshift-keda
```

The output appears similar to the following:

## Example output

```
NAME                                READY STATUS  RESTARTS  AGE
pod/custom-metrics-autoscaler-operator-5fd8d9ffd8-xt4xp  1/1   Running  0         18m

NAME                                READY UP-TO-DATE AVAILABLE AGE
deployment.apps/custom-metrics-autoscaler-operator  1/1   1         1         18m

NAME                                DESIRED CURRENT READY AGE
replicaset.apps/custom-metrics-autoscaler-operator-5fd8d9ffd8  1     1     1     18m
```

8. Install the **KedaController** custom resource, which creates the required CRDs:
  - a. In the OpenShift Container Platform web console, click **Operators** → **Installed Operators**.
  - b. Click **Custom Metrics Autoscaler**.
  - c. On the **Operator Details** page, click the **KedaController** tab.
  - d. On the **KedaController** tab, click **Create KedaController** and edit the file.

```
kind: KedaController
```

```

apiVersion: keda.sh/v1alpha1
metadata:
  name: keda
  namespace: openshift-keda
spec:
  watchNamespace: " 1
  operator:
    logLevel: info 2
    logEncoder: console 3
    caConfigMaps: 4
    - thanos-cert
    - kafka-cert
  metricsServer:
    logLevel: '0' 5
    auditConfig: 6
    logFormat: "json"
    logOutputVolumeClaim: "persistentVolumeClaimName"
  policy:
    rules:
      - level: Metadata
    omitStages: ["RequestReceived"]
    omitManagedFields: false
  lifetime:
    maxAge: "2"
    maxBackup: "1"
    maxSize: "50"
  serviceAccount: {}

```

- 1 Specifies a single namespace in which the Custom Metrics Autoscaler Operator should scale applications. Leave it blank or leave it empty to scale applications in all namespaces. This field should have a namespace or be empty. The default value is empty.
- 2 Specifies the level of verbosity for the Custom Metrics Autoscaler Operator log messages. The allowed values are **debug**, **info**, **error**. The default is **info**.
- 3 Specifies the logging format for the Custom Metrics Autoscaler Operator log messages. The allowed values are **console** or **json**. The default is **console**.
- 4 Optional: Specifies one or more config maps with CA certificates, which the Custom Metrics Autoscaler Operator can use to connect securely to TLS-enabled metrics sources.
- 5 Specifies the logging level for the Custom Metrics Autoscaler Metrics Server. The allowed values are **0** for **info** and **4** or **debug**. The default is **0**.
- 6 Activates audit logging for the Custom Metrics Autoscaler Operator and specifies the audit policy to use, as described in the "Configuring audit logging" section.

e. Click **Create** to create the KEDA controller.

### 3.4. UNDERSTANDING CUSTOM METRICS AUTOSCALER TRIGGERS

Triggers, also known as scalers, provide the metrics that the Custom Metrics Autoscaler Operator uses to scale your pods.

The custom metrics autoscaler currently supports only the Prometheus, CPU, memory, and Apache Kafka triggers.

You use a **ScaledObject** or **ScaledJob** custom resource to configure triggers for specific objects, as described in the sections that follow.

You can configure a certificate authority [to use with your scaled objects](#) or [for all scalers in the cluster](#).

### 3.4.1. Understanding the Prometheus trigger

You can scale pods based on Prometheus metrics, which can use the installed OpenShift Container Platform monitoring or an external Prometheus server as the metrics source. See "Configuring the custom metrics autoscaler to use OpenShift Container Platform monitoring" for information on the configurations required to use the OpenShift Container Platform monitoring as a source for metrics.



#### NOTE

If Prometheus is collecting metrics from the application that the custom metrics autoscaler is scaling, do not set the minimum replicas to **0** in the custom resource. If there are no application pods, the custom metrics autoscaler does not have any metrics to scale on.

#### Example scaled object with a Prometheus target

```

apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  name: prom-scaledobject
  namespace: my-namespace
spec:
  # ...
  triggers:
  - type: prometheus 1
    metadata:
      serverAddress: https://thanos-querier.openshift-monitoring.svc.cluster.local:9092 2
      namespace: kedatest 3
      metricName: http_requests_total 4
      threshold: '5' 5
      query: sum(rate(http_requests_total{job="test-app"}[1m])) 6
      authModes: basic 7
      cortexOrgID: my-org 8
      ignoreNullValues: "false" 9
      unsafeSsl: "false" 10

```

1 Specifies Prometheus as the trigger type.

2 Specifies the address of the Prometheus server. This example uses OpenShift Container Platform monitoring.

3

Optional: Specifies the namespace of the object you want to scale. This parameter is mandatory if using OpenShift Container Platform monitoring as a source for the metrics.

- 4 Specifies the name to identify the metric in the **external.metrics.k8s.io** API. If you are using more than one trigger, all metric names must be unique.
- 5 Specifies the value that triggers scaling. Must be specified as a quoted string value.
- 6 Specifies the Prometheus query to use.
- 7 Specifies the authentication method to use. Prometheus scalers support bearer authentication (**bearer**), basic authentication (**basic**), or TLS authentication (**tls**). You configure the specific authentication parameters in a trigger authentication, as discussed in a following section. As needed, you can also use a secret.
- 8 Optional: Passes the **X-Scope-OrgID** header to multi-tenant [Cortex](#) or [Mimir](#) storage for Prometheus. This parameter is required only with multi-tenant Prometheus storage, to indicate which data Prometheus should return.
- 9 Optional: Specifies how the trigger should proceed if the Prometheus target is lost.
  - If **true**, the trigger continues to operate if the Prometheus target is lost. This is the default behavior.
  - If **false**, the trigger returns an error if the Prometheus target is lost.
- 10 Optional: Specifies whether the certificate check should be skipped. For example, you might skip the check if you are running in a test environment and using self-signed certificates at the Prometheus endpoint.
  - If **false**, the certificate check is performed. This is the default behavior.
  - If **true**, the certificate check is not performed.

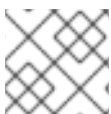


#### IMPORTANT

Skipping the check is not recommended.

### 3.4.1.1. Configuring the custom metrics autoscaler to use OpenShift Container Platform monitoring

You can use the installed OpenShift Container Platform Prometheus monitoring as a source for the metrics used by the custom metrics autoscaler. However, there are some additional configurations you must perform.



#### NOTE

These steps are not required for an external Prometheus source.

You must perform the following tasks, as described in this section:

- Create a service account.
- Create a secret that generates a token for the service account.

- Create the trigger authentication.
- Create a role.
- Add that role to the service account.
- Reference the token in the trigger authentication object used by Prometheus.

### Prerequisites

- OpenShift Container Platform monitoring must be installed.
- Monitoring of user-defined workloads must be enabled in OpenShift Container Platform monitoring, as described in the **Creating a user-defined workload monitoring config map** section.
- The Custom Metrics Autoscaler Operator must be installed.

### Procedure

1. Change to the project with the object you want to scale:

```
$ oc project my-project
```

2. Create a service account and token, if your cluster does not have one:

- a. Create a **service account** object by using the following command:

```
$ oc create serviceaccount thanos 1
```

- 1 Specifies the name of the service account.

- b. Create a **secret** YAML to generate a service account token:

```
apiVersion: v1
kind: Secret
metadata:
  name: thanos-token
  annotations:
    kubernetes.io/service-account.name: thanos 1
type: kubernetes.io/service-account-token
```

- 1 Specifies the name of the service account.

- c. Create the secret object by using the following command:

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

- d. Use the following command to locate the token assigned to the service account:

```
$ oc describe serviceaccount thanos 1
```

- 1 Specifies the name of the service account.

### Example output

```
Name:          thanos
Namespace:     my-project
Labels:        <none>
Annotations:   <none>
Image pull secrets: thanos-dockercfg-nnwgj
Mountable secrets: thanos-dockercfg-nnwgj
Tokens:        thanos-token 1
Events:        <none>
```

- 1 Use this token in the trigger authentication.

3. Create a trigger authentication with the service account token:

- a. Create a YAML file similar to the following:

```
apiVersion: keda.sh/v1alpha1
kind: TriggerAuthentication
metadata:
  name: keda-trigger-auth-prometheus
spec:
  secretTargetRef: 1
  - parameter: bearerToken 2
    name: thanos-token 3
    key: token 4
  - parameter: ca
    name: thanos-token
    key: ca.crt
```

- 1 Specifies that this object uses a secret for authorization.
- 2 Specifies the authentication parameter to supply by using the token.
- 3 Specifies the name of the token to use.
- 4 Specifies the key in the token to use with the specified parameter.

- b. Create the CR object:

```
$ oc create -f <file-name>.yaml
```

4. Create a role for reading Thanos metrics:

- a. Create a YAML file with the following parameters:

```
apiVersion: rbac.authorization.k8s.io/v1
kind: Role
metadata:
  name: thanos-metrics-reader
```

```

rules:
- apiGroups:
  - ""
  resources:
  - pods
  verbs:
  - get
- apiGroups:
  - metrics.k8s.io
  resources:
  - pods
  - nodes
  verbs:
  - get
  - list
  - watch

```

- b. Create the CR object:

```
$ oc create -f <file-name>.yaml
```

5. Create a role binding for reading Thanos metrics:

- a. Create a YAML file similar to the following:

```

apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: thanos-metrics-reader 1
  namespace: my-project 2
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: Role
  name: thanos-metrics-reader
subjects:
- kind: ServiceAccount
  name: thanos 3
  namespace: my-project 4

```

- 1** Specifies the name of the role you created.
- 2** Specifies the namespace of the object you want to scale.
- 3** Specifies the name of the service account to bind to the role.
- 4** Specifies the namespace of the object you want to scale.

- b. Create the CR object:

```
$ oc create -f <file-name>.yaml
```

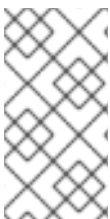
You can now deploy a scaled object or scaled job to enable autoscaling for your application, as described in "Understanding how to add custom metrics autoscalers". To use OpenShift Container Platform monitoring as the source, in the trigger, or scaler, you must include the following parameters:

- **triggers.type** must be **prometheus**
- **triggers.metadata.serverAddress** must be **https://thanos-querier.openshift-monitoring.svc.cluster.local:9092**
- **triggers.metadata.authModes** must be **bearer**
- **triggers.metadata.namespace** must be set to the namespace of the object to scale
- **triggers.authenticationRef** must point to the trigger authentication resource specified in the previous step

### 3.4.2. Understanding the CPU trigger

You can scale pods based on CPU metrics. This trigger uses cluster metrics as the source for metrics.

The custom metrics autoscaler scales the pods associated with an object to maintain the CPU usage that you specify. The autoscaler increases or decreases the number of replicas between the minimum and maximum numbers to maintain the specified CPU utilization across all pods. The memory trigger considers the memory utilization of the entire pod. If the pod has multiple containers, the memory trigger considers the total memory utilization of all containers in the pod.



#### NOTE

- This trigger cannot be used with the **ScaledJob** custom resource.
- When using a memory trigger to scale an object, the object does not scale to **0**, even if you are using multiple triggers.

#### Example scaled object with a CPU target

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  name: cpu-scaledobject
  namespace: my-namespace
spec:
  # ...
  triggers:
  - type: cpu 1
    metricType: Utilization 2
    metadata:
      value: '60' 3
  minReplicaCount: 1 4
```

- 1 Specifies CPU as the trigger type.
- 2 Specifies the type of metric to use, either **Utilization** or **AverageValue**.
- 3 Specifies the value that triggers scaling. Must be specified as a quoted string value.
  - When using **Utilization**, the target value is the average of the resource metrics across all relevant pods, represented as a percentage of the requested value of the resource for the pods.



- When using **AverageValue**, the target value is the average of the metrics across all relevant pods.

- 4 Specifies the minimum number of replicas when scaling down. For a CPU trigger, enter a value of **1** or greater, because the HPA cannot scale to zero if you are using only CPU metrics.

### 3.4.3. Understanding the memory trigger

You can scale pods based on memory metrics. This trigger uses cluster metrics as the source for metrics.

The custom metrics autoscaler scales the pods associated with an object to maintain the average memory usage that you specify. The autoscaler increases and decreases the number of replicas between the minimum and maximum numbers to maintain the specified memory utilization across all pods. The memory trigger considers the memory utilization of entire pod. If the pod has multiple containers, the memory utilization is the sum of all of the containers.



#### NOTE

- This trigger cannot be used with the **ScaledJob** custom resource.
- When using a memory trigger to scale an object, the object does not scale to **0**, even if you are using multiple triggers.

#### Example scaled object with a memory target

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  name: memory-scaledobject
  namespace: my-namespace
spec:
  # ...
  triggers:
    - type: memory 1
      metricType: Utilization 2
      metadata:
        value: '60' 3
        containerName: api 4
```

- 1 Specifies memory as the trigger type.
- 2 Specifies the type of metric to use, either **Utilization** or **AverageValue**.
- 3 Specifies the value that triggers scaling. Must be specified as a quoted string value.
  - When using **Utilization**, the target value is the average of the resource metrics across all relevant pods, represented as a percentage of the requested value of the resource for the pods.
  - When using **AverageValue**, the target value is the average of the metrics across all relevant pods.

- 4 Optional: Specifies an individual container to scale, based on the memory utilization of only that container, rather than the entire pod. In this example, only the container named **api** is to be scaled.

### 3.4.4. Understanding the Kafka trigger

You can scale pods based on an Apache Kafka topic or other services that support the Kafka protocol. The custom metrics autoscaler does not scale higher than the number of Kafka partitions, unless you set the **allowIdleConsumers** parameter to **true** in the scaled object or scaled job.



#### NOTE

If the number of consumer groups exceeds the number of partitions in a topic, the extra consumer groups remain idle. To avoid this, by default the number of replicas does not exceed:

- The number of partitions on a topic, if a topic is specified
- The number of partitions of all topics in the consumer group, if no topic is specified
- The **maxReplicaCount** specified in scaled object or scaled job CR

You can use the **allowIdleConsumers** parameter to disable these default behaviors.

#### Example scaled object with a Kafka target

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  name: kafka-scaledobject
  namespace: my-namespace
spec:
  # ...
  triggers:
  - type: kafka 1
    metadata:
      topic: my-topic 2
      bootstrapServers: my-cluster-kafka-bootstrap.openshift-operators.svc:9092 3
      consumerGroup: my-group 4
      lagThreshold: '10' 5
      activationLagThreshold: '5' 6
      offsetResetPolicy: latest 7
      allowIdleConsumers: true 8
      scaleToZeroOnInvalidOffset: false 9
      excludePersistentLag: false 10
      version: '1.0.0' 11
      partitionLimitation: '1,2,10-20,31' 12
      tls: enable 13
```

- 1 Specifies Kafka as the trigger type.
- 2 Specifies the name of the Kafka topic on which Kafka is processing the offset lag.

- 3 Specifies a comma-separated list of Kafka brokers to connect to.
- 4 Specifies the name of the Kafka consumer group used for checking the offset on the topic and processing the related lag.
- 5 Optional: Specifies the average target value that triggers scaling. Must be specified as a quoted string value. The default is **5**.
- 6 Optional: Specifies the target value for the activation phase. Must be specified as a quoted string value.
- 7 Optional: Specifies the Kafka offset reset policy for the Kafka consumer. The available values are: **latest** and **earliest**. The default is **latest**.
- 8 Optional: Specifies whether the number of Kafka replicas can exceed the number of partitions on a topic.
  - If **true**, the number of Kafka replicas can exceed the number of partitions on a topic. This allows for idle Kafka consumers.
  - If **false**, the number of Kafka replicas cannot exceed the number of partitions on a topic. This is the default.
- 9 Specifies how the trigger behaves when a Kafka partition does not have a valid offset.
  - If **true**, the consumers are scaled to zero for that partition.
  - If **false**, the scaler keeps a single consumer for that partition. This is the default.
- 10 Optional: Specifies whether the trigger includes or excludes partition lag for partitions whose current offset is the same as the current offset of the previous polling cycle.
  - If **true**, the scaler excludes partition lag in these partitions.
  - If **false**, the trigger includes all consumer lag in all partitions. This is the default.
- 11 Optional: Specifies the version of your Kafka brokers. Must be specified as a quoted string value. The default is **1.0.0**.
- 12 Optional: Specifies a comma-separated list of partition IDs to scope the scaling on. If set, only the listed IDs are considered when calculating lag. Must be specified as a quoted string value. The default is to consider all partitions.
- 13 Optional: Specifies whether to use TLS client authentication for Kafka. The default is **disable**. For information on configuring TLS, see "Understanding custom metrics autoscaler trigger authentications".

### 3.4.5. Understanding the Cron trigger

You can scale pods based on a time range.

When the time range starts, the custom metrics autoscaler scales the pods associated with an object from the configured minimum number of pods to the specified number of desired pods. At the end of the time range, the pods are scaled back to the configured minimum. The time period must be configured in [cron format](#).

The following example scales the pods associated with this scaled object from **0** to **100** from 6:00 AM to 6:30 PM India Standard Time.

### Example scaled object with a Cron trigger

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  name: cron-scaledobject
  namespace: default
spec:
  scaleTargetRef:
    name: my-deployment
  minReplicaCount: 0 1
  maxReplicaCount: 100 2
  cooldownPeriod: 300
  triggers:
  - type: cron 3
    metadata:
      timezone: Asia/Kolkata 4
      start: "0 6 * * *" 5
      end: "30 18 * * *" 6
      desiredReplicas: "100" 7
```

- 1** Specifies the minimum number of pods to scale down to at the end of the time frame.
- 2** Specifies the maximum number of replicas when scaling up. This value should be the same as **desiredReplicas**. The default is **100**.
- 3** Specifies a Cron trigger.
- 4** Specifies the timezone for the time frame. This value must be from the [IANA Time Zone Database](#).
- 5** Specifies the start of the time frame.
- 6** Specifies the end of the time frame.
- 7** Specifies the number of pods to scale to between the start and end of the time frame. This value should be the same as **maxReplicaCount**.

## 3.5. UNDERSTANDING CUSTOM METRICS AUTOSCALER TRIGGER AUTHENTICATIONS

A trigger authentication allows you to include authentication information in a scaled object or a scaled job that can be used by the associated containers. You can use trigger authentications to pass OpenShift Container Platform secrets, platform-native pod authentication mechanisms, environment variables, and so on.

You define a **TriggerAuthentication** object in the same namespace as the object that you want to scale. That trigger authentication can be used only by objects in that namespace.

Alternatively, to share credentials between objects in multiple namespaces, you can create a **ClusterTriggerAuthentication** object that can be used across all namespaces.

Trigger authentications and cluster trigger authentication use the same configuration. However, a cluster trigger authentication requires an additional **kind** parameter in the authentication reference of the scaled object.

### Example secret for Basic authentication

```
apiVersion: v1
kind: Secret
metadata:
  name: my-basic-secret
  namespace: default
data:
  username: "dXNlcm5hbWU=" 1
  password: "cGFzc3dvcmQ="
```

- 1 User name and password to supply to the trigger authentication. The values in a **data** stanza must be base-64 encoded.

### Example trigger authentication using a secret for Basic authentication

```
kind: TriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata:
  name: secret-triggerauthentication
  namespace: my-namespace 1
spec:
  secretTargetRef: 2
  - parameter: username 3
    name: my-basic-secret 4
    key: username 5
  - parameter: password
    name: my-basic-secret
    key: password
```

- 1 Specifies the namespace of the object you want to scale.
- 2 Specifies that this trigger authentication uses a secret for authorization when connecting to the metrics endpoint.
- 3 Specifies the authentication parameter to supply by using the secret.
- 4 Specifies the name of the secret to use.
- 5 Specifies the key in the secret to use with the specified parameter.

### Example cluster trigger authentication with a secret for Basic authentication

```
kind: ClusterTriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata: 1
  name: secret-cluster-triggerauthentication
spec:
```

```
secretTargetRef: 2
- parameter: username 3
  name: my-basic-secret 4
  key: username 5
- parameter: password
  name: my-basic-secret
  key: password
```

- 1 Note that no namespace is used with a cluster trigger authentication.
- 2 Specifies that this trigger authentication uses a secret for authorization when connecting to the metrics endpoint.
- 3 Specifies the authentication parameter to supply by using the secret.
- 4 Specifies the name of the secret to use.
- 5 Specifies the key in the secret to use with the specified parameter.

### Example secret with certificate authority (CA) details

```
apiVersion: v1
kind: Secret
metadata:
  name: my-secret
  namespace: my-namespace
data:
  ca-cert.pem: LS0tLS1CRUdJTjBDRVJUSUZJQ0FURS0tLS0... 1
  client-cert.pem: LS0tLS1CRUdJTjBDRVJUSUZJQ0FURS0... 2
  client-key.pem: LS0tLS1CRUdJTjBQUkIWQVRFIEtFWS0t...
```

- 1 Specifies the TLS CA Certificate for authentication of the metrics endpoint. The value must be base-64 encoded.
- 2 Specifies the TLS certificates and key for TLS client authentication. The values must be base-64 encoded.

### Example trigger authentication using a secret for CA details

```
kind: TriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata:
  name: secret-triggerauthentication
  namespace: my-namespace 1
spec:
  secretTargetRef: 2
  - parameter: key 3
    name: my-secret 4
    key: client-key.pem 5
  - parameter: ca 6
    name: my-secret 7
    key: ca-cert.pem 8
```

- 
- 1 Specifies the namespace of the object you want to scale.
- 2 Specifies that this trigger authentication uses a secret for authorization when connecting to the metrics endpoint.
- 3 Specifies the type of authentication to use.
- 4 Specifies the name of the secret to use.
- 5 Specifies the key in the secret to use with the specified parameter.
- 6 Specifies the authentication parameter for a custom CA when connecting to the metrics endpoint.
- 7 Specifies the name of the secret to use.
- 8 Specifies the key in the secret to use with the specified parameter.

### Example secret with a bearer token

```

apiVersion: v1
kind: Secret
metadata:
  name: my-secret
  namespace: my-namespace
data:
  bearerToken: "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXV" 1

```

- 1 Specifies a bearer token to use with bearer authentication. The value in a **data** stanza must be base-64 encoded.

### Example trigger authentication with a bearer token

```

kind: TriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata:
  name: token-triggerauthentication
  namespace: my-namespace 1
spec:
  secretTargetRef: 2
  - parameter: bearerToken 3
    name: my-secret 4
    key: bearerToken 5

```

- 1 Specifies the namespace of the object you want to scale.
- 2 Specifies that this trigger authentication uses a secret for authorization when connecting to the metrics endpoint.
- 3 Specifies the type of authentication to use.
- 4 Specifies the name of the secret to use.

- 5 Specifies the key in the token to use with the specified parameter.

### Example trigger authentication with an environment variable

```
kind: TriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata:
  name: env-var-triggerauthentication
  namespace: my-namespace 1
spec:
  env: 2
  - parameter: access_key 3
    name: ACCESS_KEY 4
  containerName: my-container 5
```

- 1 Specifies the namespace of the object you want to scale.
- 2 Specifies that this trigger authentication uses environment variables for authorization when connecting to the metrics endpoint.
- 3 Specify the parameter to set with this variable.
- 4 Specify the name of the environment variable.
- 5 Optional: Specify a container that requires authentication. The container must be in the same resource as referenced by **scaleTargetRef** in the scaled object.

### Example trigger authentication with pod authentication providers

```
kind: TriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata:
  name: pod-id-triggerauthentication
  namespace: my-namespace 1
spec:
  podIdentity: 2
  provider: aws-eks 3
```

- 1 Specifies the namespace of the object you want to scale.
- 2 Specifies that this trigger authentication uses a platform-native pod authentication when connecting to the metrics endpoint.
- 3 Specifies a pod identity. Supported values are **none**, **azure**, **gcp**, **aws-eks**, or **aws-kiam**. The default is **none**.

### Additional resources

- For information about OpenShift Container Platform secrets, see [Providing sensitive data to pods](#).



### 3.5.1. Using trigger authentications

You use trigger authentications and cluster trigger authentications by using a custom resource to create the authentication, then add a reference to a scaled object or scaled job.

#### Prerequisites

- The Custom Metrics Autoscaler Operator must be installed.
- If you are using a secret, the **Secret** object must exist, for example:

#### Example secret

```
apiVersion: v1
kind: Secret
metadata:
  name: my-secret
data:
  user-name: <base64_USER_NAME>
  password: <base64_USER_PASSWORD>
```

#### Procedure

1. Create the **TriggerAuthentication** or **ClusterTriggerAuthentication** object.
  - a. Create a YAML file that defines the object:

#### Example trigger authentication with a secret

```
kind: TriggerAuthentication
apiVersion: keda.sh/v1alpha1
metadata:
  name: prom-triggerauthentication
  namespace: my-namespace
spec:
  secretTargetRef:
    - parameter: user-name
      name: my-secret
      key: USER_NAME
    - parameter: password
      name: my-secret
      key: USER_PASSWORD
```

- b. Create the **TriggerAuthentication** object:

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

2. Create or edit a **ScaledObject** YAML file that uses the trigger authentication:
  - a. Create a YAML file that defines the object by running the following command:

#### Example scaled object with a trigger authentication

```
apiVersion: keda.sh/v1alpha1
```

```

kind: ScaledObject
metadata:
  name: scaledobject
  namespace: my-namespace
spec:
  scaleTargetRef:
    name: example-deployment
  maxReplicaCount: 100
  minReplicaCount: 0
  pollingInterval: 30
  triggers:
  - type: prometheus
    metadata:
      serverAddress: https://thanos-querier.openshift-monitoring.svc.cluster.local:9092
      namespace: kedatest # replace <NAMESPACE>
      metricName: http_requests_total
      threshold: '5'
      query: sum(rate(http_requests_total{job="test-app"}[1m]))
      authModes: "basic"
    authenticationRef:
      name: prom-triggerauthentication ❶
      kind: TriggerAuthentication ❷

```

- ❶ Specify the name of your trigger authentication object.
- ❷ Specify **TriggerAuthentication**. **TriggerAuthentication** is the default.

### Example scaled object with a cluster trigger authentication

```

apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  name: scaledobject
  namespace: my-namespace
spec:
  scaleTargetRef:
    name: example-deployment
  maxReplicaCount: 100
  minReplicaCount: 0
  pollingInterval: 30
  triggers:
  - type: prometheus
    metadata:
      serverAddress: https://thanos-querier.openshift-monitoring.svc.cluster.local:9092
      namespace: kedatest # replace <NAMESPACE>
      metricName: http_requests_total
      threshold: '5'
      query: sum(rate(http_requests_total{job="test-app"}[1m]))
      authModes: "basic"
    authenticationRef:
      name: prom-cluster-triggerauthentication ❶
      kind: ClusterTriggerAuthentication ❷

```

- ❶ Specify the name of your trigger authentication object.

## 2 Specify **ClusterTriggerAuthentication**.

- b. Create the scaled object by running the following command:

```
$ oc apply -f <filename>
```

## 3.6. PAUSING THE CUSTOM METRICS AUTOSCALER FOR A SCALED OBJECT

You can pause and restart the autoscaling of a workload, as needed.

For example, you might want to pause autoscaling before performing cluster maintenance or to avoid resource starvation by removing non-mission-critical workloads.

### 3.6.1. Pausing a custom metrics autoscaler

You can pause the autoscaling of a scaled object by adding the **autoscaling.keda.sh/paused-replicas** annotation to the custom metrics autoscaler for that scaled object. The custom metrics autoscaler scales the replicas for that workload to the specified value and pauses autoscaling until the annotation is removed.

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  annotations:
    autoscaling.keda.sh/paused-replicas: "4"
# ...
```

#### Procedure

1. Use the following command to edit the **ScaledObject** CR for your workload:

```
$ oc edit ScaledObject scaledobject
```

2. Add the **autoscaling.keda.sh/paused-replicas** annotation with any value:

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  annotations:
    autoscaling.keda.sh/paused-replicas: "4" 1
  creationTimestamp: "2023-02-08T14:41:01Z"
  generation: 1
  name: scaledobject
  namespace: my-project
  resourceVersion: '65729'
  uid: f5aec682-acdf-4232-a783-58b5b82f5dd0
```

- 1 Specifies that the Custom Metrics Autoscaler Operator is to scale the replicas to the specified value and stop autoscaling.

### 3.6.2. Restarting the custom metrics autoscaler for a scaled object

You can restart a paused custom metrics autoscaler by removing the **autoscaling.keda.sh/paused-replicas** annotation for that **ScaledObject**.

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  annotations:
    autoscaling.keda.sh/paused-replicas: "4"
# ...
```

#### Procedure

1. Use the following command to edit the **ScaledObject** CR for your workload:

```
$ oc edit ScaledObject scaledobject
```

2. Remove the **autoscaling.keda.sh/paused-replicas** annotation.

```
apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  annotations:
    autoscaling.keda.sh/paused-replicas: "4" 1
  creationTimestamp: "2023-02-08T14:41:01Z"
  generation: 1
  name: scaledobject
  namespace: my-project
  resourceVersion: '65729'
  uid: f5aec682-acdf-4232-a783-58b5b82f5dd0
```

- 1** Remove this annotation to restart a paused custom metrics autoscaler.

## 3.7. GATHERING AUDIT LOGS

You can gather audit logs, which are a security-relevant chronological set of records documenting the sequence of activities that have affected the system by individual users, administrators, or other components of the system.

For example, audit logs can help you understand where an autoscaling request is coming from. This is key information when backends are getting overloaded by autoscaling requests made by user applications and you need to determine which is the troublesome application.

### 3.7.1. Configuring audit logging

You can configure auditing for the Custom Metrics Autoscaler Operator by editing the **KedaController** custom resource. The logs are sent to an audit log file on a volume that is secured by using a persistent volume claim in the **KedaController** CR.

#### Prerequisites

- The Custom Metrics Autoscaler Operator must be installed.

## Procedure

1. Edit the **KedaController** custom resource to add the **auditConfig** stanza:

```
kind: KedaController
apiVersion: keda.sh/v1alpha1
metadata:
  name: keda
  namespace: openshift-keda
spec:
  # ...
  metricsServer:
  # ...
  auditConfig:
    logFormat: "json" 1
    logOutputVolumeClaim: "pvc-audit-log" 2
    policy:
      rules: 3
      - level: Metadata
      omitStages: "RequestReceived" 4
      omitManagedFields: false 5
    lifetime: 6
      maxAge: "2"
      maxBackup: "1"
      maxSize: "50"
```

- 1 Specifies the output format of the audit log, either **legacy** or **json**.
- 2 Specifies an existing persistent volume claim for storing the log data. All requests coming to the API server are logged to this persistent volume claim. If you leave this field empty, the log data is sent to stdout.
- 3 Specifies which events should be recorded and what data they should include:
  - **None**: Do not log events.
  - **Metadata**: Log only the metadata for the request, such as user, timestamp, and so forth. Do not log the request text and the response text. This is the default.
  - **Request**: Log only the metadata and the request text but not the response text. This option does not apply for non-resource requests.
  - **RequestResponse**: Log event metadata, request text, and response text. This option does not apply for non-resource requests.
- 4 Specifies stages for which no event is created.
- 5 Specifies whether to omit the managed fields of the request and response bodies from being written to the API audit log, either **true** to omit the fields or **false** to include the fields.
- 6 Specifies the size and lifespan of the audit logs.

- **maxAge:** The maximum number of days to retain audit log files, based on the timestamp encoded in their filename.
- **maxBackup:** The maximum number of audit log files to retain. Set to **0** to retain all audit log files.
- **maxSize:** The maximum size in megabytes of an audit log file before it gets rotated.

## Verification

1. View the audit log file directly:

- a. Obtain the name of the **keda-metrics-apiserver-\*** pod:

```
oc get pod -n openshift-keda
```

### Example output

```
NAME                                READY STATUS RESTARTS AGE
custom-metrics-autoscaler-operator-5cb44cd75d-9v4lv 1/1 Running 0      8m20s
keda-metrics-apiserver-65c7cc44fd-rrl4r             1/1 Running 0      2m55s
keda-operator-776cbb6768-zpj5b                     1/1 Running 0      2m55s
```

- b. View the log data by using a command similar to the following:

```
$ oc logs keda-metrics-apiserver-<hash>|grep -i metadata 1
```

- 1** Optional: You can use the **grep** command to specify the log level to display: **Metadata**, **Request**, **RequestResponse**.

For example:

```
$ oc logs keda-metrics-apiserver-65c7cc44fd-rrl4r|grep -i metadata
```

### Example output

```
...
{"kind":"Event","apiVersion":"audit.k8s.io/v1","level":"Metadata","auditID":"4c81d41b-3dab-4675-90ce-20b87ce24013","stage":"ResponseComplete","requestURI":"/healthz","verb":"get","user":{"username":"system:anonymous","groups":["system:unauthenticated"]},"sourceIPs":["10.131.0.1"],"userAgent":"kube-probe/1.28","responseStatus":{"metadata":{},"code":200},"requestReceivedTimestamp":"2023-02-16T13:00:03.554567Z","stageTimestamp":"2023-02-16T13:00:03.555032Z","annotations":{"authorization.k8s.io/decision":"allow","authorization.k8s.io/reason":""}}
...
```

2. Alternatively, you can view a specific log:

- a. Use a command similar to the following to log into the **keda-metrics-apiserver-\*** pod:

```
$ oc rsh pod/keda-metrics-apiserver-<hash> -n openshift-keda
```

For example:

```
$ oc rsh pod/keda-metrics-apiserver-65c7cc44fd-rrl4r -n openshift-keda
```

- b. Change to the **/var/audit-policy/** directory:

```
sh-4.4$ cd /var/audit-policy/
```

- c. List the available logs:

```
sh-4.4$ ls
```

### Example output

```
log-2023.02.17-14:50 policy.yaml
```

- d. View the log, as needed:

```
sh-4.4$ cat <log_name>/<pvc_name>|grep -i <log_level> 1
```

- 1** Optional: You can use the **grep** command to specify the log level to display: **Metadata, Request, RequestResponse**.

For example:

```
sh-4.4$ cat log-2023.02.17-14:50/pvc-audit-log|grep -i Request
```

### Example output

```
...
{"kind":"Event","apiVersion":"audit.k8s.io/v1","level":"Request","auditID":"63e7f68c-04ec-4f4d-8749-bf1656572a41","stage":"ResponseComplete","requestURI":"/openapi/v2","verb":"get","user":{"username":"system:aggregator","groups":["system:authenticated"]},"sourceIPs":["10.128.0.1"],"responseStatus":{"metadata":{"code":304},"requestReceivedTimestamp":"2023-02-17T13:12:55.035478Z","stageTimestamp":"2023-02-17T13:12:55.038346Z","annotations":{"authorization.k8s.io/decision":"allow","authorization.k8s.io/reason":"RBAC: allowed by ClusterRoleBinding \"system:discovery\" of ClusterRole \"system:discovery\" to Group \"system:authenticated\"}}}}
...
```

## 3.8. GATHERING DEBUGGING DATA

When opening a support case, it is helpful to provide debugging information about your cluster to Red Hat Support.

To help troubleshoot your issue, provide the following information:

- Data gathered using the **must-gather** tool.
- The unique cluster ID.

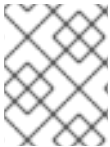
You can use the **must-gather** tool to collect data about the Custom Metrics Autoscaler Operator and its components, including the following items:

- The **openshift-keda** namespace and its child objects.
- The Custom Metric Autoscaler Operator installation objects.
- The Custom Metric Autoscaler Operator CRD objects.

### 3.8.1. Gathering debugging data

The following command runs the **must-gather** tool for the Custom Metrics Autoscaler Operator:

```
$ oc adm must-gather --image="$(oc get packagemanifests openshift-custom-metrics-autoscaler-operator \
-n openshift-marketplace \
-o jsonpath='{.status.channels[?(@.name=="stable")].currentCSVDesc.annotations.containerImage}')"
```



#### NOTE

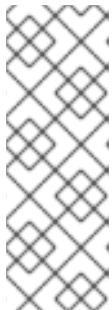
The standard OpenShift Container Platform **must-gather** command, **oc adm must-gather**, does not collect Custom Metrics Autoscaler Operator data.

#### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- The OpenShift Container Platform CLI (**oc**) installed.

#### Procedure

1. Navigate to the directory where you want to store the **must-gather** data.



#### NOTE

If your cluster is using a restricted network, you must take additional steps. If your mirror registry has a trusted CA, you must first add the trusted CA to the cluster. For all clusters on restricted networks, you must import the default **must-gather** image as an image stream by running the following command.

```
$ oc import-image is/must-gather -n openshift
```

2. Perform one of the following:

- To get only the Custom Metrics Autoscaler Operator **must-gather** data, use the following command:

```
$ oc adm must-gather --image="$(oc get packagemanifests openshift-custom-metrics-
```



```

autoscaler-operator \
-n openshift-marketplace \
-o jsonpath='{.status.channels[?
(@.name=="stable")].currentCSVDesc.annotations.containerImage}'"

```

The custom image for the **must-gather** command is pulled directly from the Operator package manifests, so that it works on any cluster where the Custom Metric Autoscaler Operator is available.

- To gather the default **must-gather** data in addition to the Custom Metric Autoscaler Operator information:
  - a. Use the following command to obtain the Custom Metrics Autoscaler Operator image and set it as an environment variable:

```

$ IMAGE="$(oc get packagemanifests openshift-custom-metrics-autoscaler-operator
\
-n openshift-marketplace \
-o jsonpath='{.status.channels[?
(@.name=="stable")].currentCSVDesc.annotations.containerImage}')"

```

- b. Use the **oc adm must-gather** with the Custom Metrics Autoscaler Operator image:

```
$ oc adm must-gather --image-stream=openshift/must-gather --image=${IMAGE}
```

### Example 3.1. Example must-gather output for the Custom Metric Autoscaler

```

├── openshift-keda
│   ├── apps
│   │   ├── daemonsets.yaml
│   │   ├── deployments.yaml
│   │   ├── replicasetsets.yaml
│   │   └── statefulsets.yaml
│   ├── apps.openshift.io
│   │   └── deploymentconfigs.yaml
│   ├── autoscaling
│   │   └── horizontalpodautoscalers.yaml
│   ├── batch
│   │   ├── cronjobs.yaml
│   │   └── jobs.yaml
│   ├── build.openshift.io
│   │   ├── buildconfigs.yaml
│   │   └── builds.yaml
│   ├── core
│   │   ├── configmaps.yaml
│   │   ├── endpoints.yaml
│   │   ├── events.yaml
│   │   ├── persistentvolumeclaims.yaml
│   │   ├── pods.yaml
│   │   ├── replicationcontrollers.yaml
│   │   ├── secrets.yaml
│   │   └── services.yaml
│   ├── discovery.k8s.io
│   │   └── endpointslices.yaml
│   └── image.openshift.io

```

```

├── imagestreams.yaml
├── k8s.ovn.org
│   ├── egressfirewalls.yaml
│   └── egressqoses.yaml
├── keda.sh
│   ├── kedacontrollers
│   │   └── keda.yaml
│   ├── scaledobjects
│   │   └── example-scaledobject.yaml
│   └── triggerauthentications
│       └── example-triggerauthentication.yaml
├── monitoring.coreos.com
│   └── servicemonitors.yaml
├── networking.k8s.io
│   └── networkpolicies.yaml
├── openshift-keda.yaml
├── pods
│   ├── custom-metrics-autoscaler-operator-58bd9f458-ptgwx
│   │   ├── custom-metrics-autoscaler-operator
│   │   │   └── custom-metrics-autoscaler-operator
│   │   │       └── logs
│   │   │           ├── current.log
│   │   │           ├── previous.insecure.log
│   │   │           └── previous.log
│   │   └── custom-metrics-autoscaler-operator-58bd9f458-ptgwx.yaml
│   ├── custom-metrics-autoscaler-operator-58bd9f458-thbsh
│   │   ├── custom-metrics-autoscaler-operator
│   │   │   └── custom-metrics-autoscaler-operator
│   │   │       └── logs
│   ├── keda-metrics-apiserver-65c7cc44fd-6wq4g
│   │   ├── keda-metrics-apiserver
│   │   │   └── keda-metrics-apiserver
│   │   │       └── logs
│   │   │           ├── current.log
│   │   │           ├── previous.insecure.log
│   │   │           └── previous.log
│   │   └── keda-metrics-apiserver-65c7cc44fd-6wq4g.yaml
│   └── keda-operator-776cbb6768-fb6m5
│       ├── keda-operator
│       │   ├── keda-operator
│       │   │   └── logs
│       │   │       ├── current.log
│       │   │       ├── previous.insecure.log
│       │   │       └── previous.log
│       └── keda-operator-776cbb6768-fb6m5.yaml
├── policy
│   └── poddisruptionbudgets.yaml
├── route.openshift.io
│   └── routes.yaml

```

3. Create a compressed file from the **must-gather** directory that was created in your working directory. For example, on a computer that uses a Linux operating system, run the following command:

```
$ tar cvaf must-gather.tar.gz must-gather.local.5421342344627712289/ 1
```

**1** Replace **must-gather-local.5421342344627712289/** with the actual directory name.

4. Attach the compressed file to your support case on the [Red Hat Customer Portal](#).

## 3.9. VIEWING OPERATOR METRICS

The Custom Metrics Autoscaler Operator exposes ready-to-use metrics that it pulls from the on-cluster monitoring component. You can query the metrics by using the Prometheus Query Language (PromQL) to analyze and diagnose issues. All metrics are reset when the controller pod restarts.

### 3.9.1. Accessing performance metrics

You can access the metrics and run queries by using the OpenShift Container Platform web console.

#### Procedure

1. Select the **Administrator** perspective in the OpenShift Container Platform web console.
2. Select **Observe** → **Metrics**.
3. To create a custom query, add your PromQL query to the **Expression** field.
4. To add multiple queries, select **Add Query**.

#### 3.9.1.1. Provided Operator metrics

The Custom Metrics Autoscaler Operator exposes the following metrics, which you can view by using the OpenShift Container Platform web console.

**Table 3.1. Custom Metric Autoscaler Operator metrics**

Metric name	Description
<b>keda_scaler_activity</b>	Whether the particular scaler is active or inactive. A value of <b>1</b> indicates the scaler is active; a value of <b>0</b> indicates the scaler is inactive.
<b>keda_scaler_metrics_value</b>	The current value for each scaler’s metric, which is used by the Horizontal Pod Autoscaler (HPA) in computing the target average.
<b>keda_scaler_metrics_latency</b>	The latency of retrieving the current metric from each scaler.
<b>keda_scaler_errors</b>	The number of errors that have occurred for each scaler.
<b>keda_scaler_errors_total</b>	The total number of errors encountered for all scalers.
<b>keda_scaled_object_errors</b>	The number of errors that have occurred for each scaled object.

Metric name	Description
<b>keda_resource_totals</b>	The total number of Custom Metrics Autoscaler custom resources in each namespace for each custom resource type.
<b>keda_trigger_totals</b>	The total number of triggers by trigger type.

### Custom Metrics Autoscaler Admission webhook metrics

The Custom Metrics Autoscaler Admission webhook also exposes the following Prometheus metrics.

Metric name	Description
<b>keda_scaled_object_validation_total</b>	The number of scaled object validations.
<b>keda_scaled_object_validation_errors</b>	The number of validation errors.

## 3.10. UNDERSTANDING HOW TO ADD CUSTOM METRICS AUTOSCALERS

To add a custom metrics autoscaler, create a **ScaledObject** custom resource for a deployment, stateful set, or custom resource. Create a **ScaledJob** custom resource for a job.

You can create only one scaled object for each workload that you want to scale. Also, you cannot use a scaled object and the horizontal pod autoscaler (HPA) on the same workload.

### 3.10.1. Adding a custom metrics autoscaler to a workload

You can create a custom metrics autoscaler for a workload that is created by a **Deployment**, **StatefulSet**, or **custom resource** object.

#### Prerequisites

- The Custom Metrics Autoscaler Operator must be installed.
- If you use a custom metrics autoscaler for scaling based on CPU or memory:
  - Your cluster administrator must have properly configured cluster metrics. You can use the **oc describe PodMetrics <pod-name>** command to determine if metrics are configured. If metrics are configured, the output appears similar to the following, with CPU and Memory displayed under Usage.

```
$ oc describe PodMetrics openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
```

#### Example output

```

Name:      openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
Namespace: openshift-kube-scheduler
Labels:    <none>
Annotations: <none>
API Version: metrics.k8s.io/v1beta1
Containers:
  Name: wait-for-host-port
  Usage:
    Memory: 0
  Name: scheduler
  Usage:
    Cpu: 8m
    Memory: 45440Ki
Kind: PodMetrics
Metadata:
  Creation Timestamp: 2019-05-23T18:47:56Z
  Self Link: /apis/metrics.k8s.io/v1beta1/namespaces/openshift-kube-
scheduler/pods/openshift-kube-scheduler-ip-10-0-135-131.ec2.internal
Timestamp: 2019-05-23T18:47:56Z
Window: 1m0s
Events: <none>

```

- The pods associated with the object you want to scale must include specified memory and CPU limits. For example:

### Example pod spec

```

apiVersion: v1
kind: Pod
# ...
spec:
  containers:
  - name: app
    image: images.my-company.example/app:v4
  resources:
    limits:
      memory: "128Mi"
      cpu: "500m"
# ...

```

### Procedure

1. Create a YAML file similar to the following. Only the name **<2>**, object name **<4>**, and object kind **<5>** are required:

### Example scaled object

```

apiVersion: keda.sh/v1alpha1
kind: ScaledObject
metadata:
  annotations:
    autoscaling.keda.sh/paused-replicas: "0" 1
  name: scaledobject 2
  namespace: my-namespace

```

```

spec:
  scaleTargetRef:
    apiVersion: apps/v1 3
    name: example-deployment 4
    kind: Deployment 5
    envSourceContainerName: .spec.template.spec.containers[0] 6
  cooldownPeriod: 200 7
  maxReplicaCount: 100 8
  minReplicaCount: 0 9
  metricsServer: 10
  auditConfig:
    logFormat: "json"
    logOutputVolumeClaim: "persistentVolumeClaimName"
    policy:
      rules:
        - level: Metadata
        omitStages: "RequestReceived"
        omitManagedFields: false
      lifetime:
        maxAge: "2"
        maxBackup: "1"
        maxSize: "50"
  fallback: 11
    failureThreshold: 3
    replicas: 6
  pollingInterval: 30 12
  advanced:
    restoreToOriginalReplicaCount: false 13
    horizontalPodAutoscalerConfig:
      name: keda-hpa-scale-down 14
      behavior: 15
        scaleDown:
          stabilizationWindowSeconds: 300
          policies:
            - type: Percent
              value: 100
            periodSeconds: 15
  triggers:
    - type: prometheus 16
      metadata:
        serverAddress: https://thanos-querier.openshift-monitoring.svc.cluster.local:9092
        namespace: kedatest
        metricName: http_requests_total
        threshold: '5'
        query: sum(rate(http_requests_total{job="test-app"}[1m]))
        authModes: basic
      authenticationRef: 17
        name: prom-triggerauthentication
        kind: TriggerAuthentication

```

- 1** Optional: Specifies that the Custom Metrics Autoscaler Operator is to scale the replicas to the specified value and stop autoscaling, as described in the "Pausing the custom metrics autoscaler for a workload" section.

- 2 Specifies a name for this custom metrics autoscaler.
- 3 Optional: Specifies the API version of the target resource. The default is **apps/v1**.
- 4 Specifies the name of the object that you want to scale.
- 5 Specifies the **kind** as **Deployment**, **StatefulSet** or **CustomResource**.
- 6 Optional: Specifies the name of the container in the target resource, from which the custom metrics autoscaler gets environment variables holding secrets and so forth. The default is **.spec.template.spec.containers[0]**.
- 7 Optional. Specifies the period in seconds to wait after the last trigger is reported before scaling the deployment back to **0** if the **minReplicaCount** is set to **0**. The default is **300**.
- 8 Optional: Specifies the maximum number of replicas when scaling up. The default is **100**.
- 9 Optional: Specifies the minimum number of replicas when scaling down.
- 10 Optional: Specifies the parameters for audit logs. as described in the "Configuring audit logging" section.
- 11 Optional: Specifies the number of replicas to fall back to if a scaler fails to get metrics from the source for the number of times defined by the **failureThreshold** parameter. For more information on fallback behavior, see the [KEDA documentation](#).
- 12 Optional: Specifies the interval in seconds to check each trigger on. The default is **30**.
- 13 Optional: Specifies whether to scale back the target resource to the original replica count after the scaled object is deleted. The default is **false**, which keeps the replica count as it is when the scaled object is deleted.
- 14 Optional: Specifies a name for the horizontal pod autoscaler. The default is **keda-hpa-{scaled-object-name}**.
- 15 Optional: Specifies a scaling policy to use to control the rate to scale pods up or down, as described in the "Scaling policies" section.
- 16 Specifies the trigger to use as the basis for scaling, as described in the "Understanding the custom metrics autoscaler triggers" section. This example uses OpenShift Container Platform monitoring.
- 17 Optional: Specifies a trigger authentication or a cluster trigger authentication. For more information, see *Understanding the custom metrics autoscaler trigger authentication* in the *Additional resources* section.
  - Enter **TriggerAuthentication** to use a trigger authentication. This is the default.
  - Enter **ClusterTriggerAuthentication** to use a cluster trigger authentication.

2. Create the custom metrics autoscaler by running the following command:

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

## Verification

- View the command output to verify that the custom metrics autoscaler was created:

```
$ oc get scaledobject <scaled_object_name>
```

### Example output

```
NAME          SCALETARGETKIND  SCALETARGETNAME  MIN  MAX  TRIGGERS
AUTHENTICATION  READY  ACTIVE  FALLBACK  AGE
scaledobject  apps/v1.Deployment  example-deployment  0  50  prometheus  prom-
triggerauthentication  True  True  True  17s
```

Note the following fields in the output:

- **TRIGGERS:** Indicates the trigger, or scaler, that is being used.
- **AUTHENTICATION:** Indicates the name of any trigger authentication being used.
- **READY:** Indicates whether the scaled object is ready to start scaling:
  - If **True**, the scaled object is ready.
  - If **False**, the scaled object is not ready because of a problem in one or more of the objects you created.
- **ACTIVE:** Indicates whether scaling is taking place:
  - If **True**, scaling is taking place.
  - If **False**, scaling is not taking place because there are no metrics or there is a problem in one or more of the objects you created.
- **FALLBACK:** Indicates whether the custom metrics autoscaler is able to get metrics from the source
  - If **False**, the custom metrics autoscaler is getting metrics.
  - If **True**, the custom metrics autoscaler is getting metrics because there are no metrics or there is a problem in one or more of the objects you created.

### 3.10.2. Adding a custom metrics autoscaler to a job

You can create a custom metrics autoscaler for any **Job** object.



#### IMPORTANT

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

For more information about the support scope of Red Hat Technology Preview features, see [Technology Preview Features Support Scope](#).

#### Prerequisites



- The Custom Metrics Autoscaler Operator must be installed.

## Procedure

1. Create a YAML file similar to the following:

```

kind: ScaledJob
apiVersion: keda.sh/v1alpha1
metadata:
  name: scaledjob
  namespace: my-namespace
spec:
  failedJobsHistoryLimit: 5
  jobTargetRef:
    activeDeadlineSeconds: 600 1
    backoffLimit: 6 2
    parallelism: 1 3
    completions: 1 4
    template: 5
      metadata:
        name: pi
      spec:
        containers:
          - name: pi
            image: perl
            command: ["perl", "-Mbignum=bpi", "-wle", "print bpi(2000)"]
  maxReplicaCount: 100 6
  pollingInterval: 30 7
  successfulJobsHistoryLimit: 5 8
  failedJobsHistoryLimit: 5 9
  envSourceContainerName: 10
  rolloutStrategy: gradual 11
  scalingStrategy: 12
    strategy: "custom"
    customScalingQueueLengthDeduction: 1
    customScalingRunningJobPercentage: "0.5"
  pendingPodConditions:
    - "Ready"
    - "PodScheduled"
    - "AnyOtherCustomPodCondition"
  multipleScalersCalculation : "max"
  triggers:
    - type: prometheus 13
      metadata:
        serverAddress: https://thanos-querier.openshift-monitoring.svc.cluster.local:9092
        namespace: kedatest
        metricName: http_requests_total
        threshold: '5'
        query: sum(rate(http_requests_total{job="test-app"}[1m]))
        authModes: "bearer"
      authenticationRef: 14
        name: prom-cluster-triggerauthentication

```

- 1 Specifies the maximum duration the job can run.
- 2 Specifies the number of retries for a job. The default is **6**.
- 3 Optional: Specifies how many pod replicas a job should run in parallel; defaults to **1**.
  - For non-parallel jobs, leave unset. When unset, the default is **1**.
- 4 Optional: Specifies how many successful pod completions are needed to mark a job completed.
  - For non-parallel jobs, leave unset. When unset, the default is **1**.
  - For parallel jobs with a fixed completion count, specify the number of completions.
  - For parallel jobs with a work queue, leave unset. When unset the default is the value of the **parallelism** parameter.
- 5 Specifies the template for the pod the controller creates.
- 6 Optional: Specifies the maximum number of replicas when scaling up. The default is **100**.
- 7 Optional: Specifies the interval in seconds to check each trigger on. The default is **30**.
- 8 Optional: Specifies the number of successful finished jobs should be kept. The default is **100**.
- 9 Optional: Specifies how many failed jobs should be kept. The default is **100**.
- 10 Optional: Specifies the name of the container in the target resource, from which the custom autoscaler gets environment variables holding secrets and so forth. The default is **.spec.template.spec.containers[0]**.
- 11 Optional: Specifies whether existing jobs are terminated whenever a scaled job is being updated:
  - **default**: The autoscaler terminates an existing job if its associated scaled job is updated. The autoscaler recreates the job with the latest specs.
  - **gradual**: The autoscaler does not terminate an existing job if its associated scaled job is updated. The autoscaler creates new jobs with the latest specs.
- 12 Optional: Specifies a scaling strategy: **default**, **custom**, or **accurate**. The default is **default**. For more information, see the link in the "Additional resources" section that follows.
- 13 Specifies the trigger to use as the basis for scaling, as described in the "Understanding the custom metrics autoscaler triggers" section.
- 14 Optional: Specifies a trigger authentication or a cluster trigger authentication. For more information, see *Understanding the custom metrics autoscaler trigger authentication* in the *Additional resources* section.
  - Enter **TriggerAuthentication** to use a trigger authentication. This is the default.
  - Enter **ClusterTriggerAuthentication** to use a cluster trigger authentication.

2. Create the custom metrics autoscaler by running the following command:

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

### Verification

- View the command output to verify that the custom metrics autoscaler was created:

```
$ oc get scaledjob <scaled_job_name>
```

### Example output

```
NAME      MAX TRIGGERS  AUTHENTICATION      READY  ACTIVE  AGE
scaledjob 100 prometheus  prom-triggerauthentication  True   True    8s
```

Note the following fields in the output:

- **TRIGGERS:** Indicates the trigger, or scaler, that is being used.
- **AUTHENTICATION:** Indicates the name of any trigger authentication being used.
- **READY:** Indicates whether the scaled object is ready to start scaling:
  - If **True**, the scaled object is ready.
  - If **False**, the scaled object is not ready because of a problem in one or more of the objects you created.
- **ACTIVE:** Indicates whether scaling is taking place:
  - If **True**, scaling is taking place.
  - If **False**, scaling is not taking place because there are no metrics or there is a problem in one or more of the objects you created.

### 3.10.3. Additional resources

- [Understanding custom metrics autoscaler trigger authentications](#)

## 3.11. REMOVING THE CUSTOM METRICS AUTOSCALER OPERATOR

You can remove the custom metrics autoscaler from your OpenShift Container Platform cluster. After removing the Custom Metrics Autoscaler Operator, remove other components associated with the Operator to avoid potential issues.



### NOTE

Delete the **KedaController** custom resource (CR) first. If you do not delete the **KedaController** CR, OpenShift Container Platform can hang when you delete the **openshift-keda** project. If you delete the Custom Metrics Autoscaler Operator before deleting the CR, you are not able to delete the CR.


### 3.11.1. Uninstalling the Custom Metrics Autoscaler Operator

Use the following procedure to remove the custom metrics autoscaler from your OpenShift Container Platform cluster.

## Prerequisites

- The Custom Metrics Autoscaler Operator must be installed.

## Procedure

1. In the OpenShift Container Platform web console, click **Operators** → **Installed Operators**.
2. Switch to the **openshift-keda** project.
3. Remove the **KedaController** custom resource.
  - a. Find the **CustomMetricsAutoscaler** Operator and click the **KedaController** tab.
  - b. Find the custom resource, and then click **Delete KedaController**.
  - c. Click **Uninstall**.
4. Remove the Custom Metrics Autoscaler Operator:
  - a. Click **Operators** → **Installed Operators**.
  - b. Find the **CustomMetricsAutoscaler** Operator and click the **Options** menu  and select **Uninstall Operator**.
  - c. Click **Uninstall**.
5. Optional: Use the OpenShift CLI to remove the custom metrics autoscaler components:
  - a. Delete the custom metrics autoscaler CRDs:
    - **clustertriggerauthentications.keda.sh**
    - **kedacontrollers.keda.sh**
    - **scaledjobs.keda.sh**
    - **scaledobjects.keda.sh**
    - **triggerauthentications.keda.sh**

```
$ oc delete crd clustertriggerauthentications.keda.sh kedacontrollers.keda.sh  
scaledjobs.keda.sh scaledobjects.keda.sh triggerauthentications.keda.sh
```

Deleting the CRDs removes the associated roles, cluster roles, and role bindings. However, there might be a few cluster roles that must be manually deleted.

- b. List any custom metrics autoscaler cluster roles:

```
$ oc get clusterrole | grep keda.sh
```

- c. Delete the listed custom metrics autoscaler cluster roles. For example:

```
┆ $ oc delete clusterrole.keda.sh-v1alpha1-admin
```

- d. List any custom metrics autoscaler cluster role bindings:

```
┆ $ oc get clusterrolebinding | grep keda.sh
```

- e. Delete the listed custom metrics autoscaler cluster role bindings. For example:

```
┆ $ oc delete clusterrolebinding.keda.sh-v1alpha1-admin
```

6. Delete the custom metrics autoscaler project:

```
┆ $ oc delete project openshift-keda
```

7. Delete the Cluster Metric Autoscaler Operator:

```
┆ $ oc delete operator/openshift-custom-metrics-autoscaler-operator.openshift-keda
```

## CHAPTER 4. CONTROLLING POD PLACEMENT ONTO NODES (SCHEDULING)

### 4.1. CONTROLLING POD PLACEMENT USING THE SCHEDULER

Pod scheduling is an internal process that determines placement of new pods onto nodes within the cluster.

The scheduler code has a clean separation that watches new pods as they get created and identifies the most suitable node to host them. It then creates bindings (pod to node bindings) for the pods using the master API.

#### Default pod scheduling

OpenShift Container Platform comes with a default scheduler that serves the needs of most users. The default scheduler uses both inherent and customization tools to determine the best fit for a pod.

#### Advanced pod scheduling

In situations where you might want more control over where new pods are placed, the OpenShift Container Platform advanced scheduling features allow you to configure a pod so that the pod is required or has a preference to run on a particular node or alongside a specific pod.

You can control pod placement by using the following scheduling features:

- [Scheduler profiles](#)
- [Pod affinity and anti-affinity rules](#)
- [Node affinity](#)
- [Node selectors](#)
- [Taints and tolerations](#)
- [Node overcommitment](#)

#### 4.1.1. About the default scheduler

The default OpenShift Container Platform pod scheduler is responsible for determining the placement of new pods onto nodes within the cluster. It reads data from the pod and finds a node that is a good fit based on configured profiles. It is completely independent and exists as a standalone solution. It does not modify the pod; it creates a binding for the pod that ties the pod to the particular node.

##### 4.1.1.1. Understanding default scheduling

The existing generic scheduler is the default platform-provided scheduler *engine* that selects a node to host the pod in a three-step operation:

#### Filters the nodes

The available nodes are filtered based on the constraints or requirements specified. This is done by running each node through the list of filter functions called *predicates*, or *filters*.

#### Prioritizes the filtered list of nodes

This is achieved by passing each node through a series of *priority*, or *scoring*, functions that assign it a score between 0 - 10, with 0 indicating a bad fit and 10 indicating a good fit to host the pod. The

scheduler configuration can also take in a simple *weight* (positive numeric value) for each scoring function. The node score provided by each scoring function is multiplied by the weight (default weight for most scores is 1) and then combined by adding the scores for each node provided by all the scores. This weight attribute can be used by administrators to give higher importance to some scores.

### Selects the best fit node

The nodes are sorted based on their scores and the node with the highest score is selected to host the pod. If multiple nodes have the same high score, then one of them is selected at random.

## 4.1.2. Scheduler use cases

One of the important use cases for scheduling within OpenShift Container Platform is to support flexible affinity and anti-affinity policies.

### 4.1.2.1. Infrastructure topological levels

Administrators can define multiple topological levels for their infrastructure (nodes) by specifying labels on nodes. For example: **region=r1, zone=z1, rack=s1**.

These label names have no particular meaning and administrators are free to name their infrastructure levels anything, such as city/building/room. Also, administrators can define any number of levels for their infrastructure topology, with three levels usually being adequate (such as: **regions → zones → racks**). Administrators can specify affinity and anti-affinity rules at each of these levels in any combination.

### 4.1.2.2. Affinity

Administrators should be able to configure the scheduler to specify affinity at any topological level, or even at multiple levels. Affinity at a particular level indicates that all pods that belong to the same service are scheduled onto nodes that belong to the same level. This handles any latency requirements of applications by allowing administrators to ensure that peer pods do not end up being too geographically separated. If no node is available within the same affinity group to host the pod, then the pod is not scheduled.

If you need greater control over where the pods are scheduled, see [Controlling pod placement on nodes using node affinity rules](#) and [Placing pods relative to other pods using affinity and anti-affinity rules](#).

These advanced scheduling features allow administrators to specify which node a pod can be scheduled on and to force or reject scheduling relative to other pods.

### 4.1.2.3. Anti-affinity

Administrators should be able to configure the scheduler to specify anti-affinity at any topological level, or even at multiple levels. Anti-affinity (or 'spread') at a particular level indicates that all pods that belong to the same service are spread across nodes that belong to that level. This ensures that the application is well spread for high availability purposes. The scheduler tries to balance the service pods across all applicable nodes as evenly as possible.

If you need greater control over where the pods are scheduled, see [Controlling pod placement on nodes using node affinity rules](#) and [Placing pods relative to other pods using affinity and anti-affinity rules](#).

These advanced scheduling features allow administrators to specify which node a pod can be scheduled on and to force or reject scheduling relative to other pods.

## 4.2. SCHEDULING PODS USING A SCHEDULER PROFILE

You can configure OpenShift Container Platform to use a scheduling profile to schedule pods onto nodes within the cluster.

### 4.2.1. About scheduler profiles

You can specify a scheduler profile to control how pods are scheduled onto nodes.

The following scheduler profiles are available:

#### LowNodeUtilization

This profile attempts to spread pods evenly across nodes to get low resource usage per node. This profile provides the default scheduler behavior.

#### HighNodeUtilization

This profile attempts to place as many pods as possible on to as few nodes as possible. This minimizes node count and has high resource usage per node.

#### NoScoring

This is a low-latency profile that strives for the quickest scheduling cycle by disabling all score plugins. This might sacrifice better scheduling decisions for faster ones.

### 4.2.2. Configuring a scheduler profile

You can configure the scheduler to use a scheduler profile.

#### Prerequisites

- Access to the cluster as a user with the **cluster-admin** role.

#### Procedure

1. Edit the **Scheduler** object:

```
$ oc edit scheduler cluster
```

2. Specify the profile to use in the **spec.profile** field:

```
apiVersion: config.openshift.io/v1
kind: Scheduler
metadata:
  name: cluster
#...
spec:
  mastersSchedulable: false
  profile: HighNodeUtilization 1
#...
```

- 1** Set to **LowNodeUtilization**, **HighNodeUtilization**, or **NoScoring**.

3. Save the file to apply the changes.



## 4.3. PLACING PODS RELATIVE TO OTHER PODS USING AFFINITY AND ANTI-AFFINITY RULES

Affinity is a property of pods that controls the nodes on which they prefer to be scheduled. Anti-affinity is a property of pods that prevents a pod from being scheduled on a node.

In OpenShift Container Platform, *pod affinity* and *pod anti-affinity* allow you to constrain which nodes your pod is eligible to be scheduled on based on the key-value labels on other pods.

### 4.3.1. Understanding pod affinity

*Pod affinity* and *pod anti-affinity* allow you to constrain which nodes your pod is eligible to be scheduled on based on the key/value labels on other pods.

- Pod affinity can tell the scheduler to locate a new pod on the same node as other pods if the label selector on the new pod matches the label on the current pod.
- Pod anti-affinity can prevent the scheduler from locating a new pod on the same node as pods with the same labels if the label selector on the new pod matches the label on the current pod.

For example, using affinity rules, you could spread or pack pods within a service or relative to pods in other services. Anti-affinity rules allow you to prevent pods of a particular service from scheduling on the same nodes as pods of another service that are known to interfere with the performance of the pods of the first service. Or, you could spread the pods of a service across nodes, availability zones, or availability sets to reduce correlated failures.

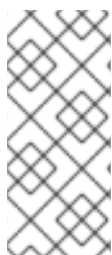


#### NOTE

A label selector might match pods with multiple pod deployments. Use unique combinations of labels when configuring anti-affinity rules to avoid matching pods.

There are two types of pod affinity rules: *required* and *preferred*.

Required rules **must** be met before a pod can be scheduled on a node. Preferred rules specify that, if the rule is met, the scheduler tries to enforce the rules, but does not guarantee enforcement.



#### NOTE

Depending on your pod priority and preemption settings, the scheduler might not be able to find an appropriate node for a pod without violating affinity requirements. If so, a pod might not be scheduled.

To prevent this situation, carefully configure pod affinity with equal-priority pods.

You configure pod affinity/anti-affinity through the **Pod** spec files. You can specify a required rule, a preferred rule, or both. If you specify both, the node must first meet the required rule, then attempts to meet the preferred rule.

The following example shows a **Pod** spec configured for pod affinity and anti-affinity.

In this example, the pod affinity rule indicates that the pod can schedule onto a node only if that node has at least one already-running pod with a label that has the key **security** and value **S1**. The pod anti-affinity rule says that the pod prefers to not schedule onto a node if that node is already running a pod with label having key **security** and value **S2**.

## Sample Pod config file with pod affinity

```

apiVersion: v1
kind: Pod
metadata:
  name: with-pod-affinity
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  affinity:
    podAffinity: 1
      requiredDuringSchedulingIgnoredDuringExecution: 2
      - labelSelector:
          matchExpressions:
            - key: security 3
              operator: In 4
              values:
                - S1 5
          topologyKey: topology.kubernetes.io/zone
    containers:
      - name: with-pod-affinity
        image: docker.io/ocpqe/hello-pod
        securityContext:
          allowPrivilegeEscalation: false
        capabilities:
          drop: [ALL]

```

**1** Stanza to configure pod affinity.

**2** Defines a required rule.

**3** **5** The key and value (label) that must be matched to apply the rule.

**4** The operator represents the relationship between the label on the existing pod and the set of values in the **matchExpression** parameters in the specification for the new pod. Can be **In**, **NotIn**, **Exists**, or **DoesNotExist**.

## Sample Pod config file with pod anti-affinity

```

apiVersion: v1
kind: Pod
metadata:
  name: with-pod-antiaffinity
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  affinity:
    podAntiAffinity: 1
      preferredDuringSchedulingIgnoredDuringExecution: 2

```

```

- weight: 100 3
  podAffinityTerm:
    labelSelector:
      matchExpressions:
        - key: security 4
          operator: In 5
          values:
            - S2
      topologyKey: kubernetes.io/hostname
  containers:
    - name: with-pod-affinity
      image: docker.io/ocpqe/hello-pod
      securityContext:
        allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]

```

- 1 Stanza to configure pod anti-affinity.
- 2 Defines a preferred rule.
- 3 Specifies a weight for a preferred rule. The node with the highest weight is preferred.
- 4 Description of the pod label that determines when the anti-affinity rule applies. Specify a key and value for the label.
- 5 The operator represents the relationship between the label on the existing pod and the set of values in the **matchExpression** parameters in the specification for the new pod. Can be **In**, **NotIn**, **Exists**, or **DoesNotExist**.



#### NOTE

If labels on a node change at runtime such that the affinity rules on a pod are no longer met, the pod continues to run on the node.

### 4.3.2. Configuring a pod affinity rule

The following steps demonstrate a simple two-pod configuration that creates pod with a label and a pod that uses affinity to allow scheduling with that pod.



#### NOTE

You cannot add an affinity directly to a scheduled pod.

#### Procedure

1. Create a pod with a specific label in the pod spec:
  - a. Create a YAML file with the following content:

```

apiVersion: v1
kind: Pod
metadata:
  name: security-s1

```

```

labels:
  security: S1
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - name: security-s1
    image: docker.io/ocpqe/hello-pod
    securityContext:
      runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault

```

- b. Create the pod.

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

2. When creating other pods, configure the following parameters to add the affinity:

- a. Create a YAML file with the following content:

```

apiVersion: v1
kind: Pod
metadata:
  name: security-s1-east
# ...
spec:
  affinity: ❶
  podAffinity:
    requiredDuringSchedulingIgnoredDuringExecution: ❷
    - labelSelector:
        matchExpressions:
          - key: security ❸
            values:
              - S1
            operator: In ❹
        topologyKey: topology.kubernetes.io/zone ❺
# ...

```

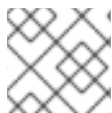
- ❶ Adds a pod affinity.
- ❷ Configures the **requiredDuringSchedulingIgnoredDuringExecution** parameter or the **preferredDuringSchedulingIgnoredDuringExecution** parameter.
- ❸ Specifies the **key** and **values** that must be met. If you want the new pod to be scheduled with the other pod, use the same **key** and **values** parameters as the label on the first pod.
- ❹ Specifies an **operator**. The operator can be **In**, **NotIn**, **Exists**, or **DoesNotExist**. For example, use the operator **In** to require the label to be in the node.
- ❺ Specify a **topologyKey**, which is a prepopulated [Kubernetes label](#) that the system uses to denote such a topology domain.

- b. Create the pod.

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

### 4.3.3. Configuring a pod anti-affinity rule

The following steps demonstrate a simple two-pod configuration that creates pod with a label and a pod that uses an anti-affinity preferred rule to attempt to prevent scheduling with that pod.



#### NOTE

You cannot add an affinity directly to a scheduled pod.

#### Procedure

1. Create a pod with a specific label in the pod spec:
  - a. Create a YAML file with the following content:

```
apiVersion: v1
kind: Pod
metadata:
  name: security-s1
  labels:
    security: S1
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: security-s1
    image: docker.io/ocpqe/hello-pod
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
```

- b. Create the pod.

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

2. When creating other pods, configure the following parameters:
  - a. Create a YAML file with the following content:

```
apiVersion: v1
kind: Pod
metadata:
  name: security-s2-east
  # ...
spec:
  # ...
  affinity: ❶
```

```

podAntiAffinity:
  preferredDuringSchedulingIgnoredDuringExecution: ❷
  - weight: 100 ❸
  podAffinityTerm:
    labelSelector:
      matchExpressions:
        - key: security ❹
          values:
            - S1
          operator: In ❺
    topologyKey: kubernetes.io/hostname ❻
# ...

```

- ❶ Adds a pod anti-affinity.
- ❷ Configures the **requiredDuringSchedulingIgnoredDuringExecution** parameter or the **preferredDuringSchedulingIgnoredDuringExecution** parameter.
- ❸ For a preferred rule, specifies a weight for the node, 1-100. The node that with highest weight is preferred.
- ❹ Specifies the **key** and **values** that must be met. If you want the new pod to not be scheduled with the other pod, use the same **key** and **values** parameters as the label on the first pod.
- ❺ Specifies an **operator**. The operator can be **In**, **NotIn**, **Exists**, or **DoesNotExist**. For example, use the operator **In** to require the label to be in the node.
- ❻ Specifies a **topologyKey**, which is a prepopulated [Kubernetes label](#) that the system uses to denote such a topology domain.

b. Create the pod.

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

#### 4.3.4. Sample pod affinity and anti-affinity rules

The following examples demonstrate pod affinity and pod anti-affinity.

##### 4.3.4.1. Pod Affinity

The following example demonstrates pod affinity for pods with matching labels and label selectors.

- The pod **team4** has the label **team:4**.

```

apiVersion: v1
kind: Pod
metadata:
  name: team4
  labels:
    team: "4"
# ...
spec:
  securityContext:

```

```

runAsNonRoot: true
seccompProfile:
  type: RuntimeDefault
containers:
- name: ocp
  image: docker.io/ocpqe/hello-pod
  securityContext:
    allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
# ...

```

- The pod **team4a** has the label selector **team:4** under **podAffinity**.

```

apiVersion: v1
kind: Pod
metadata:
  name: team4a
# ...
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  affinity:
    podAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
      - labelSelector:
          matchExpressions:
          - key: team
            operator: In
            values:
            - "4"
        topologyKey: kubernetes.io/hostname
  containers:
  - name: pod-affinity
    image: docker.io/ocpqe/hello-pod
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
# ...

```

- The **team4a** pod is scheduled on the same node as the **team4** pod.

#### 4.3.4.2. Pod Anti-affinity

The following example demonstrates pod anti-affinity for pods with matching labels and label selectors.

- The pod **pod-s1** has the label **security:s1**.

```

apiVersion: v1
kind: Pod
metadata:
  name: pod-s1

```

```

labels:
  security: s1
# ...
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: ocp
    image: docker.io/ocpqe/hello-pod
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
# ...

```

- The pod **pod-s2** has the label selector **security:s1** under **podAntiAffinity**.

```

apiVersion: v1
kind: Pod
metadata:
  name: pod-s2
# ...
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  affinity:
    podAntiAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
      - labelSelector:
          matchExpressions:
          - key: security
            operator: In
            values:
            - s1
        topologyKey: kubernetes.io/hostname
  containers:
  - name: pod-antiaffinity
    image: docker.io/ocpqe/hello-pod
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
# ...

```

- The pod **pod-s2** cannot be scheduled on the same node as **pod-s1**.

#### 4.3.4.3. Pod Affinity with no Matching Labels

The following example demonstrates pod affinity for pods without matching labels and label selectors.

- The pod **pod-s1** has the label **security:s1**.



```

apiVersion: v1
kind: Pod
metadata:
  name: pod-s1
  labels:
    security: s1
# ...
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: ocp
    image: docker.io/ocpqe/hello-pod
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
# ...

```

- The pod **pod-s2** has the label selector **security:s2**.

```

apiVersion: v1
kind: Pod
metadata:
  name: pod-s2
# ...
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  affinity:
    podAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
      - labelSelector:
          matchExpressions:
          - key: security
            operator: In
            values:
            - s2
        topologyKey: kubernetes.io/hostname
  containers:
  - name: pod-affinity
    image: docker.io/ocpqe/hello-pod
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
# ...

```

- The pod **pod-s2** is not scheduled unless there is a node with a pod that has the **security:s2** label. If there is no other pod with that label, the new pod remains in a pending state:

#### Example output

**Example output**

NAME	READY	STATUS	RESTARTS	AGE	IP	NODE
pod-s2	0/1	Pending	0	32s	<none>	

### 4.3.5. Controlling where an Operator is installed

### 4.3.6. Using pod affinity and anti-affinity to control where an Operator is installed

By default, when you install an Operator, OpenShift Container Platform installs the Operator pod to one of your worker nodes randomly. However, there might be situations where you want that pod scheduled on a specific node or set of nodes.

The following examples describe situations where you might want to schedule an Operator pod to a specific node or set of nodes:

- If an Operator requires a particular platform, such as **amd64** or **arm64**
- If an Operator requires a particular operating system, such as Linux or Windows
- If you want Operators that work together scheduled on the same host or on hosts located on the same rack
- If you want Operators dispersed throughout the infrastructure to avoid downtime due to network or hardware issues

You can control where an Operator pod is installed by adding node affinity, pod affinity, or pod anti-affinity constraints to the Operator's **Subscription** object. Node affinity is a set of rules used by the scheduler to determine where a pod can be placed. Pod affinity enables you to ensure that related pods are scheduled to the same node. Pod anti-affinity allows you to prevent a pod from being scheduled on a node.

You can control where an Operator pod is installed by adding a pod affinity or anti-affinity to the Operator's **Subscription** object.

The following examples show how to use node affinity or pod anti-affinity to install an instance of the Custom Metrics Autoscaler Operator to a specific node in the cluster:

The following example shows how to use pod anti-affinity to prevent the installation the Custom Metrics Autoscaler Operator from any node that has pods with a specific label:

#### Pod affinity example that places the Operator pod on one or more specific nodes

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: openshift-custom-metrics-autoscaler-operator
  namespace: openshift-keda
spec:
  name: my-package
  source: my-operators
  sourceNamespace: operator-registries
config:
  affinity:
    podAffinity: 1
```

```

requiredDuringSchedulingIgnoredDuringExecution:
  - labelSelector:
      matchExpressions:
        - key: app
          operator: In
          values:
            - test
      topologyKey: kubernetes.io/hostname
#...

```

- 1 A pod affinity that places the Operator's pod on a node that has pods with the **app=test** label.

### Pod anti-affinity example that prevents the Operator pod from one or more specific nodes

```

apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: openshift-custom-metrics-autoscaler-operator
  namespace: openshift-keda
spec:
  name: my-package
  source: my-operators
  sourceNamespace: operator-registries
config:
  affinity:
    podAntiAffinity: 1
      requiredDuringSchedulingIgnoredDuringExecution:
        - labelSelector:
            matchExpressions:
              - key: cpu
                operator: In
                values:
                  - high
            topologyKey: kubernetes.io/hostname
#...

```

- 1 A pod anti-affinity that prevents the Operator's pod from being scheduled on a node that has pods with the **cpu=high** label.

### Procedure

To control the placement of an Operator pod, complete the following steps:

1. Install the Operator as usual.
2. If needed, ensure that your nodes are labeled to properly respond to the affinity.
3. Edit the Operator **Subscription** object to add an affinity:

```

apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: openshift-custom-metrics-autoscaler-operator
  namespace: openshift-keda

```

```

spec:
  name: my-package
  source: my-operators
  sourceNamespace: operator-registries
  config:
    affinity:
      podAntiAffinity: 1
      requiredDuringSchedulingIgnoredDuringExecution:
        podAffinityTerm:
          labelSelector:
            matchExpressions:
              - key: kubernetes.io/hostname
                operator: In
                values:
                  - ip-10-0-185-229.ec2.internal
          topologyKey: topology.kubernetes.io/zone
#...

```

- 1 Add a **podAffinity** or **podAntiAffinity**.

## Verification

- To ensure that the pod is deployed on the specific node, run the following command:

```
$ oc get pods -o wide
```

### Example output

```

NAME                                READY STATUS RESTARTS AGE IP
NODE                                NOMINATED NODE READINESS GATES
custom-metrics-autoscaler-operator-5dcc45d656-bhshg 1/1 Running 0 50s
10.131.0.20 ip-10-0-185-229.ec2.internal <none> <none>

```

## 4.4. CONTROLLING POD PLACEMENT ON NODES USING NODE AFFINITY RULES

Affinity is a property of pods that controls the nodes on which they prefer to be scheduled.

In OpenShift Container Platform node affinity is a set of rules used by the scheduler to determine where a pod can be placed. The rules are defined using custom labels on the nodes and label selectors specified in pods.

### 4.4.1. Understanding node affinity

Node affinity allows a pod to specify an affinity towards a group of nodes it can be placed on. The node does not have control over the placement.

For example, you could configure a pod to only run on a node with a specific CPU or in a specific availability zone.

There are two types of node affinity rules: *required* and *preferred*.

Required rules **must** be met before a pod can be scheduled on a node. Preferred rules specify that, if the rule is met, the scheduler tries to enforce the rules, but does not guarantee enforcement.



## NOTE

If labels on a node change at runtime that results in an node affinity rule on a pod no longer being met, the pod continues to run on the node.

You configure node affinity through the **Pod** spec file. You can specify a required rule, a preferred rule, or both. If you specify both, the node must first meet the required rule, then attempts to meet the preferred rule.

The following example is a **Pod** spec with a rule that requires the pod be placed on a node with a label whose key is **e2e-az-NorthSouth** and whose value is either **e2e-az-North** or **e2e-az-South**:

### Example pod configuration file with a node affinity required rule

```
apiVersion: v1
kind: Pod
metadata:
  name: with-node-affinity
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  affinity:
    nodeAffinity: 1
      requiredDuringSchedulingIgnoredDuringExecution: 2
        nodeSelectorTerms:
          - matchExpressions:
              - key: e2e-az-NorthSouth 3
                operator: In 4
                values:
                  - e2e-az-North 5
                  - e2e-az-South 6
        containers:
          - name: with-node-affinity
            image: docker.io/ocpqe/hello-pod
            securityContext:
              allowPrivilegeEscalation: false
            capabilities:
              drop: [ALL]
# ...
```

- 1 The stanza to configure node affinity.
- 2 Defines a required rule.
- 3 5 6 The key/value pair (label) that must be matched to apply the rule.
- 4 The operator represents the relationship between the label on the node and the set of values in the **matchExpression** parameters in the **Pod** spec. This value can be **In**, **NotIn**, **Exists**, or **DoesNotExist**, **Lt**, or **Gt**.

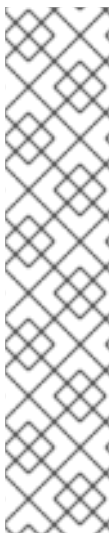
The following example is a node specification with a preferred rule that a node with a label whose key is **e2e-az-EastWest** and whose value is either **e2e-az-East** or **e2e-az-West** is preferred for the pod:

### Example pod configuration file with a node affinity preferred rule

```
apiVersion: v1
kind: Pod
metadata:
  name: with-node-affinity
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  affinity:
    nodeAffinity: ❶
      preferredDuringSchedulingIgnoredDuringExecution: ❷
        - weight: 1 ❸
          preference:
            matchExpressions:
              - key: e2e-az-EastWest ❹
                operator: In ❺
                values:
                  - e2e-az-East ❻
                  - e2e-az-West ❼
    containers:
      - name: with-node-affinity
        image: docker.io/ocpqe/hello-pod
        securityContext:
          allowPrivilegeEscalation: false
        capabilities:
          drop: [ALL]
# ...
```

- ❶ The stanza to configure node affinity.
- ❷ Defines a preferred rule.
- ❸ Specifies a weight for a preferred rule. The node with highest weight is preferred.
- ❹❻❼ The key/value pair (label) that must be matched to apply the rule.
- ❺ The operator represents the relationship between the label on the node and the set of values in the **matchExpression** parameters in the **Pod** spec. This value can be **In**, **NotIn**, **Exists**, or **DoesNotExist**, **Lt**, or **Gt**.

There is no explicit *node anti-affinity* concept, but using the **NotIn** or **DoesNotExist** operator replicates that behavior.



## NOTE

If you are using node affinity and node selectors in the same pod configuration, note the following:

- If you configure both **nodeSelector** and **nodeAffinity**, both conditions must be satisfied for the pod to be scheduled onto a candidate node.
- If you specify multiple **nodeSelectorTerms** associated with **nodeAffinity** types, then the pod can be scheduled onto a node if one of the **nodeSelectorTerms** is satisfied.
- If you specify multiple **matchExpressions** associated with **nodeSelectorTerms**, then the pod can be scheduled onto a node only if all **matchExpressions** are satisfied.

### 4.4.2. Configuring a required node affinity rule

Required rules **must** be met before a pod can be scheduled on a node.

#### Procedure

The following steps demonstrate a simple configuration that creates a node and a pod that the scheduler is required to place on the node.

1. Add a label to a node using the **oc label node** command:

```
$ oc label node node1 e2e-az-name=e2e-az1
```

#### TIP

You can alternatively apply the following YAML to add the label:

```
kind: Node
apiVersion: v1
metadata:
  name: <node_name>
  labels:
    e2e-az-name: e2e-az1
#...
```

2. Create a pod with a specific label in the pod spec:
  - a. Create a YAML file with the following content:



## NOTE

You cannot add an affinity directly to a scheduled pod.

#### Example output

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

```

name: s1
spec:
  affinity: ❶
    nodeAffinity:
      requiredDuringSchedulingIgnoredDuringExecution: ❷
        nodeSelectorTerms:
          - matchExpressions:
              - key: e2e-az-name ❸
                values:
                  - e2e-az1
                  - e2e-az2
                operator: In ❹
#...
```

- ❶ Adds a pod affinity.
- ❷ Configures the **requiredDuringSchedulingIgnoredDuringExecution** parameter.
- ❸ Specifies the **key** and **values** that must be met. If you want the new pod to be scheduled on the node you edited, use the same **key** and **values** parameters as the label in the node.
- ❹ Specifies an **operator**. The operator can be **In**, **NotIn**, **Exists**, or **DoesNotExist**. For example, use the operator **In** to require the label to be in the node.

b. Create the pod:

```
$ oc create -f <file-name>.yaml
```

### 4.4.3. Configuring a preferred node affinity rule

Preferred rules specify that, if the rule is met, the scheduler tries to enforce the rules, but does not guarantee enforcement.

#### Procedure

The following steps demonstrate a simple configuration that creates a node and a pod that the scheduler tries to place on the node.

1. Add a label to a node using the **oc label node** command:

```
$ oc label node node1 e2e-az-name=e2e-az3
```

2. Create a pod with a specific label:
  - a. Create a YAML file with the following content:



#### NOTE

You cannot add an affinity directly to a scheduled pod.

```

apiVersion: v1
kind: Pod
```



```

metadata:
  name: s1
spec:
  affinity: ❶
  nodeAffinity:
    preferredDuringSchedulingIgnoredDuringExecution: ❷
    - weight: ❸
      preference:
        matchExpressions:
          - key: e2e-az-name ❹
            values:
              - e2e-az3
            operator: In ❺
#...

```

- ❶ Adds a pod affinity.
- ❷ Configures the **preferredDuringSchedulingIgnoredDuringExecution** parameter.
- ❸ Specifies a weight for the node, as a number 1-100. The node with highest weight is preferred.
- ❹ Specifies the **key** and **values** that must be met. If you want the new pod to be scheduled on the node you edited, use the same **key** and **values** parameters as the label in the node.
- ❺ Specifies an **operator**. The operator can be **In**, **NotIn**, **Exists**, or **DoesNotExist**. For example, use the operator **In** to require the label to be in the node.

b. Create the pod.

```
$ oc create -f <file-name>.yaml
```

#### 4.4.4. Sample node affinity rules

The following examples demonstrate node affinity.

##### 4.4.4.1. Node affinity with matching labels

The following example demonstrates node affinity for a node and pod with matching labels:

- The Node1 node has the label **zone:us**:

```
$ oc label node node1 zone=us
```

**TIP**

You can alternatively apply the following YAML to add the label:

```
kind: Node
apiVersion: v1
metadata:
  name: <node_name>
  labels:
    zone: us
#...
```

- The pod-s1 pod has the **zone** and **us** key/value pair under a required node affinity rule:

```
$ cat pod-s1.yaml
```

**Example output**

```
apiVersion: v1
kind: Pod
metadata:
  name: pod-s1
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - image: "docker.io/ocpqe/hello-pod"
    name: hello-pod
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
  affinity:
    nodeAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
        nodeSelectorTerms:
        - matchExpressions:
          - key: "zone"
            operator: In
            values:
            - us
#...
```

- The pod-s1 pod can be scheduled on Node1:

```
$ oc get pod -o wide
```

**Example output**

```
NAME    READY   STATUS    RESTARTS  AGE   IP        NODE
pod-s1  1/1     Running   0          4m   IP1      node1
```

#### 4.4.4.2. Node affinity with no matching labels

The following example demonstrates node affinity for a node and pod without matching labels:

- The Node1 node has the label **zone:emea**:

```
$ oc label node node1 zone=emea
```

#### TIP

You can alternatively apply the following YAML to add the label:

```
kind: Node
apiVersion: v1
metadata:
  name: <node_name>
  labels:
    zone: emea
#...
```

- The pod-s1 pod has the **zone** and **us** key/value pair under a required node affinity rule:

```
$ cat pod-s1.yaml
```

#### Example output

```
apiVersion: v1
kind: Pod
metadata:
  name: pod-s1
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - image: "docker.io/ocpqe/hello-pod"
    name: hello-pod
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
  affinity:
    nodeAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
        nodeSelectorTerms:
        - matchExpressions:
          - key: "zone"
            operator: In
            values:
            - us
#...
```

- The pod-s1 pod cannot be scheduled on Node1:

```
$ oc describe pod pod-s1
```

### Example output

```
...
Events:
  FirstSeen LastSeen Count From              SubObjectPath  Type           Reason
  -----
  1m         33s         8    default-scheduler Warning        FailedScheduling  No nodes are
  available that match all of the following predicates:: MatchNodeSelector (1).
```

## 4.4.5. Controlling where an Operator is installed

### 4.4.6. Using node affinity to control where an Operator is installed

By default, when you install an Operator, OpenShift Container Platform installs the Operator pod to one of your worker nodes randomly. However, there might be situations where you want that pod scheduled on a specific node or set of nodes.

The following examples describe situations where you might want to schedule an Operator pod to a specific node or set of nodes:

- If an Operator requires a particular platform, such as **amd64** or **arm64**
- If an Operator requires a particular operating system, such as Linux or Windows
- If you want Operators that work together scheduled on the same host or on hosts located on the same rack
- If you want Operators dispersed throughout the infrastructure to avoid downtime due to network or hardware issues

You can control where an Operator pod is installed by adding node affinity, pod affinity, or pod anti-affinity constraints to the Operator's **Subscription** object. Node affinity is a set of rules used by the scheduler to determine where a pod can be placed. Pod affinity enables you to ensure that related pods are scheduled to the same node. Pod anti-affinity allows you to prevent a pod from being scheduled on a node.

You can control where an Operator pod is installed by adding a node affinity constraints to the Operator's **Subscription** object.

The following examples show how to use node affinity or pod anti-affinity to install an instance of the Custom Metrics Autoscaler Operator to a specific node in the cluster: The following examples show how to use node affinity to install an instance of the Custom Metrics Autoscaler Operator to a specific node in the cluster:

#### Node affinity example that places the Operator pod on a specific node

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
```

```

name: openshift-custom-metrics-autoscaler-operator
namespace: openshift-keda
spec:
  name: my-package
  source: my-operators
  sourceNamespace: operator-registries
  config:
    affinity:
      nodeAffinity: ❶
      requiredDuringSchedulingIgnoredDuringExecution:
        nodeSelectorTerms:
          - matchExpressions:
              - key: kubernetes.io/hostname
                operator: In
              values:
                - ip-10-0-163-94.us-west-2.compute.internal
#...
```

- ❶ A node affinity that requires the Operator's pod to be scheduled on a node named **ip-10-0-163-94.us-west-2.compute.internal**.

### Node affinity example that places the Operator pod on a node with a specific platform

```

apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: openshift-custom-metrics-autoscaler-operator
  namespace: openshift-keda
spec:
  name: my-package
  source: my-operators
  sourceNamespace: operator-registries
  config:
    affinity:
      nodeAffinity: ❶
      requiredDuringSchedulingIgnoredDuringExecution:
        nodeSelectorTerms:
          - matchExpressions:
              - key: kubernetes.io/arch
                operator: In
              values:
                - arm64
              - key: kubernetes.io/os
                operator: In
              values:
                - linux
#...
```

- ❶ A node affinity that requires the Operator's pod to be scheduled on a node with the **kubernetes.io/arch=arm64** and **kubernetes.io/os=linux** labels.

### Procedure

To control the placement of an Operator pod, complete the following steps:

1. Install the Operator as usual.
2. If needed, ensure that your nodes are labeled to properly respond to the affinity.
3. Edit the Operator **Subscription** object to add an affinity:

```

apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: openshift-custom-metrics-autoscaler-operator
  namespace: openshift-keda
spec:
  name: my-package
  source: my-operators
  sourceNamespace: operator-registries
  config:
    affinity: 1
      nodeAffinity:
        requiredDuringSchedulingIgnoredDuringExecution:
          nodeSelectorTerms:
            - matchExpressions:
                - key: kubernetes.io/hostname
                  operator: In
                  values:
                    - ip-10-0-185-229.ec2.internal
#...
```

- 1 Add a **nodeAffinity**, **podAffinity**, or **podAntiAffinity**. See the Additional resources section that follows for information about creating the affinity.

Add a **nodeAffinity**.

## Verification

- To ensure that the pod is deployed on the specific node, run the following command:

```
$ oc get pods -o wide
```

### Example output

```

NAME                                READY STATUS  RESTARTS  AGE  IP
NODE                                NOMINATED NODE  READINESS GATES
custom-metrics-autoscaler-operator-5dcc45d656-bhshg  1/1   Running  0        50s
10.131.0.20 ip-10-0-185-229.ec2.internal <none>    <none>
```

## 4.4.7. Additional resources

- [Understanding how to update labels on nodes](#)

## 4.5. PLACING PODS ONTO OVERCOMMITTED NODES

In an *overcommitted* state, the sum of the container compute resource requests and limits exceeds the resources available on the system. Overcommitment might be desirable in development environments where a trade-off of guaranteed performance for capacity is acceptable.

Requests and limits enable administrators to allow and manage the overcommitment of resources on a node. The scheduler uses requests for scheduling your container and providing a minimum service guarantee. Limits constrain the amount of compute resource that may be consumed on your node.

### 4.5.1. Understanding overcommitment

Requests and limits enable administrators to allow and manage the overcommitment of resources on a node. The scheduler uses requests for scheduling your container and providing a minimum service guarantee. Limits constrain the amount of compute resource that may be consumed on your node.

OpenShift Container Platform administrators can control the level of overcommit and manage container density on nodes by configuring masters to override the ratio between request and limit set on developer containers. In conjunction with a per-project **LimitRange** object specifying limits and defaults, this adjusts the container limit and request to achieve the desired level of overcommit.



#### NOTE

That these overrides have no effect if no limits have been set on containers. Create a **LimitRange** object with default limits, per individual project, or in the project template, to ensure that the overrides apply.

After these overrides, the container limits and requests must still be validated by any **LimitRange** object in the project. It is possible, for example, for developers to specify a limit close to the minimum limit, and have the request then be overridden below the minimum limit, causing the pod to be forbidden. This unfortunate user experience should be addressed with future work, but for now, configure this capability and **LimitRange** objects with caution.

### 4.5.2. Understanding nodes overcommitment

In an overcommitted environment, it is important to properly configure your node to provide best system behavior.

When the node starts, it ensures that the kernel tunable flags for memory management are set properly. The kernel should never fail memory allocations unless it runs out of physical memory.

To ensure this behavior, OpenShift Container Platform configures the kernel to always overcommit memory by setting the **vm.overcommit\_memory** parameter to **1**, overriding the default operating system setting.

OpenShift Container Platform also configures the kernel not to panic when it runs out of memory by setting the **vm.panic\_on\_oom** parameter to **0**. A setting of 0 instructs the kernel to call `oom_killer` in an Out of Memory (OOM) condition, which kills processes based on priority.

You can view the current setting by running the following commands on your nodes:

```
$ sysctl -a |grep commit
```

#### Example output

```
#...
vm.overcommit_memory = 0
#...
```

```
$ sysctl -a |grep panic
```

### Example output

```
#...
vm.panic_on_oom = 0
#...
```



#### NOTE

The above flags should already be set on nodes, and no further action is required.

You can also perform the following configurations for each node:

- Disable or enforce CPU limits using CPU CFS quotas
- Reserve resources for system processes
- Reserve memory across quality of service tiers

## 4.6. CONTROLLING POD PLACEMENT USING NODE TAINTS

Taints and tolerations allow the node to control which pods should (or should not) be scheduled on them.

### 4.6.1. Understanding taints and tolerations

A *taint* allows a node to refuse a pod to be scheduled unless that pod has a matching *toleration*.

You apply taints to a node through the **Node** specification (**NodeSpec**) and apply tolerations to a pod through the **Pod** specification (**PodSpec**). When you apply a taint a node, the scheduler cannot place a pod on that node unless the pod can tolerate the taint.

#### Example taint in a node specification

```
apiVersion: v1
kind: Node
metadata:
  name: my-node
#...
spec:
  taints:
  - effect: NoExecute
    key: key1
    value: value1
#...
```

#### Example toleration in a Pod spec



```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: "key1"
    operator: "Equal"
    value: "value1"
    effect: "NoExecute"
    tolerationSeconds: 3600
#...

```

Taints and tolerations consist of a key, value, and effect.

**Table 4.1. Taint and toleration components**

Parameter	Description						
<b>key</b>	The <b>key</b> is any string, up to 253 characters. The key must begin with a letter or number, and may contain letters, numbers, hyphens, dots, and underscores.						
<b>value</b>	The <b>value</b> is any string, up to 63 characters. The value must begin with a letter or number, and may contain letters, numbers, hyphens, dots, and underscores.						
<b>effect</b>	<p>The effect is one of the following:</p> <table border="1"> <tbody> <tr> <td><b>NoSchedule</b> <sup>[1]</sup></td> <td> <ul style="list-style-type: none"> <li>• New pods that do not match the taint are not scheduled onto that node.</li> <li>• Existing pods on the node remain.</li> </ul> </td> </tr> <tr> <td><b>PreferNoSchedule</b></td> <td> <ul style="list-style-type: none"> <li>• New pods that do not match the taint might be scheduled onto that node, but the scheduler tries not to.</li> <li>• Existing pods on the node remain.</li> </ul> </td> </tr> <tr> <td><b>NoExecute</b></td> <td> <ul style="list-style-type: none"> <li>• New pods that do not match the taint cannot be scheduled onto that node.</li> <li>• Existing pods on the node that do not have a matching toleration are removed.</li> </ul> </td> </tr> </tbody> </table>	<b>NoSchedule</b> <sup>[1]</sup>	<ul style="list-style-type: none"> <li>• New pods that do not match the taint are not scheduled onto that node.</li> <li>• Existing pods on the node remain.</li> </ul>	<b>PreferNoSchedule</b>	<ul style="list-style-type: none"> <li>• New pods that do not match the taint might be scheduled onto that node, but the scheduler tries not to.</li> <li>• Existing pods on the node remain.</li> </ul>	<b>NoExecute</b>	<ul style="list-style-type: none"> <li>• New pods that do not match the taint cannot be scheduled onto that node.</li> <li>• Existing pods on the node that do not have a matching toleration are removed.</li> </ul>
<b>NoSchedule</b> <sup>[1]</sup>	<ul style="list-style-type: none"> <li>• New pods that do not match the taint are not scheduled onto that node.</li> <li>• Existing pods on the node remain.</li> </ul>						
<b>PreferNoSchedule</b>	<ul style="list-style-type: none"> <li>• New pods that do not match the taint might be scheduled onto that node, but the scheduler tries not to.</li> <li>• Existing pods on the node remain.</li> </ul>						
<b>NoExecute</b>	<ul style="list-style-type: none"> <li>• New pods that do not match the taint cannot be scheduled onto that node.</li> <li>• Existing pods on the node that do not have a matching toleration are removed.</li> </ul>						

Parameter	Description				
<b>operator</b>	<table border="1"> <tr> <td><b>Equal</b></td> <td>The <b>key/value/effect</b> parameters must match. This is the default.</td> </tr> <tr> <td><b>Exists</b></td> <td>The <b>key/effect</b> parameters must match. You must leave a blank <b>value</b> parameter, which matches any.</td> </tr> </table>	<b>Equal</b>	The <b>key/value/effect</b> parameters must match. This is the default.	<b>Exists</b>	The <b>key/effect</b> parameters must match. You must leave a blank <b>value</b> parameter, which matches any.
	<b>Equal</b>	The <b>key/value/effect</b> parameters must match. This is the default.			
<b>Exists</b>	The <b>key/effect</b> parameters must match. You must leave a blank <b>value</b> parameter, which matches any.				

- If you add a **NoSchedule** taint to a control plane node, the node must have the **node-role.kubernetes.io/master=:NoSchedule** taint, which is added by default.

For example:

```

apiVersion: v1
kind: Node
metadata:
  annotations:
    machine.openshift.io/machine: openshift-machine-api/ci-ln-62s7gtb-f76d1-v8jxv-master-0
    machineconfiguration.openshift.io/currentConfig: rendered-master-
cdc1ab7da414629332cc4c3926e6e59c
  name: my-node
#...
spec:
  taints:
  - effect: NoSchedule
    key: node-role.kubernetes.io/master
#...

```

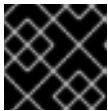
A toleration matches a taint:

- If the **operator** parameter is set to **Equal**:
  - the **key** parameters are the same;
  - the **value** parameters are the same;
  - the **effect** parameters are the same.
- If the **operator** parameter is set to **Exists**:
  - the **key** parameters are the same;
  - the **effect** parameters are the same.

The following taints are built into OpenShift Container Platform:

- **node.kubernetes.io/not-ready**: The node is not ready. This corresponds to the node condition **Ready=False**.

- **node.kubernetes.io/unreachable**: The node is unreachable from the node controller. This corresponds to the node condition **Ready=Unknown**.
- **node.kubernetes.io/memory-pressure**: The node has memory pressure issues. This corresponds to the node condition **MemoryPressure=True**.
- **node.kubernetes.io/disk-pressure**: The node has disk pressure issues. This corresponds to the node condition **DiskPressure=True**.
- **node.kubernetes.io/network-unavailable**: The node network is unavailable.
- **node.kubernetes.io/unschedulable**: The node is unschedulable.
- **node.cloudprovider.kubernetes.io/uninitialized**: When the node controller is started with an external cloud provider, this taint is set on a node to mark it as unusable. After a controller from the cloud-controller-manager initializes this node, the kubelet removes this taint.
- **node.kubernetes.io/pid-pressure**: The node has pid pressure. This corresponds to the node condition **PIDPressure=True**.



### IMPORTANT

OpenShift Container Platform does not set a default pid.available **evictionHard**.

#### 4.6.1.1. Understanding how to use toleration seconds to delay pod evictions

You can specify how long a pod can remain bound to a node before being evicted by specifying the **tolerationSeconds** parameter in the **Pod** specification or **MachineSet** object. If a taint with the **NoExecute** effect is added to a node, a pod that does tolerate the taint, which has the **tolerationSeconds** parameter, the pod is not evicted until that time period expires.

#### Example output

```
apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: "key1"
    operator: "Equal"
    value: "value1"
    effect: "NoExecute"
    tolerationSeconds: 3600
#...
```

Here, if this pod is running but does not have a matching toleration, the pod stays bound to the node for 3,600 seconds and then be evicted. If the taint is removed before that time, the pod is not evicted.

#### 4.6.1.2. Understanding how to use multiple taints

You can put multiple taints on the same node and multiple tolerations on the same pod. OpenShift Container Platform processes multiple taints and tolerations as follows:

1. Process the taints for which the pod has a matching toleration.
2. The remaining unmatched taints have the indicated effects on the pod:
  - If there is at least one unmatched taint with effect **NoSchedule**, OpenShift Container Platform cannot schedule a pod onto that node.
  - If there is no unmatched taint with effect **NoSchedule** but there is at least one unmatched taint with effect **PreferNoSchedule**, OpenShift Container Platform tries to not schedule the pod onto the node.
  - If there is at least one unmatched taint with effect **NoExecute**, OpenShift Container Platform evicts the pod from the node if it is already running on the node, or the pod is not scheduled onto the node if it is not yet running on the node.
    - Pods that do not tolerate the taint are evicted immediately.
    - Pods that tolerate the taint without specifying **tolerationSeconds** in their **Pod** specification remain bound forever.
    - Pods that tolerate the taint with a specified **tolerationSeconds** remain bound for the specified amount of time.

For example:

- Add the following taints to the node:

```
$ oc adm taint nodes node1 key1=value1:NoSchedule
```

```
$ oc adm taint nodes node1 key1=value1:NoExecute
```

```
$ oc adm taint nodes node1 key2=value2:NoSchedule
```

- The pod has the following tolerations:

```
apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: "key1"
    operator: "Equal"
    value: "value1"
    effect: "NoSchedule"
  - key: "key1"
    operator: "Equal"
    value: "value1"
    effect: "NoExecute"
#...
```

In this case, the pod cannot be scheduled onto the node, because there is no toleration matching the third taint. The pod continues running if it is already running on the node when the taint is added, because the third taint is the only one of the three that is not tolerated by the pod.

### 4.6.1.3. Understanding pod scheduling and node conditions (taint node by condition)

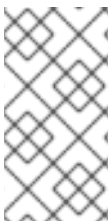
The Taint Nodes By Condition feature, which is enabled by default, automatically taints nodes that report conditions such as memory pressure and disk pressure. If a node reports a condition, a taint is added until the condition clears. The taints have the **NoSchedule** effect, which means no pod can be scheduled on the node unless the pod has a matching toleration.

The scheduler checks for these taints on nodes before scheduling pods. If the taint is present, the pod is scheduled on a different node. Because the scheduler checks for taints and not the actual node conditions, you configure the scheduler to ignore some of these node conditions by adding appropriate pod tolerations.

To ensure backward compatibility, the daemon set controller automatically adds the following tolerations to all daemons:

- `node.kubernetes.io/memory-pressure`
- `node.kubernetes.io/disk-pressure`
- `node.kubernetes.io/unschedulable` (1.10 or later)
- `node.kubernetes.io/network-unavailable` (host network only)

You can also add arbitrary tolerations to daemon sets.



#### NOTE

The control plane also adds the **node.kubernetes.io/memory-pressure** toleration on pods that have a QoS class. This is because Kubernetes manages pods in the **Guaranteed** or **Burstable** QoS classes. The new **BestEffort** pods do not get scheduled onto the affected node.

### 4.6.1.4. Understanding evicting pods by condition (taint-based evictions)

The Taint-Based Evictions feature, which is enabled by default, evicts pods from a node that experiences specific conditions, such as **not-ready** and **unreachable**. When a node experiences one of these conditions, OpenShift Container Platform automatically adds taints to the node, and starts evicting and rescheduling the pods on different nodes.

Taint Based Evictions have a **NoExecute** effect, where any pod that does not tolerate the taint is evicted immediately and any pod that does tolerate the taint will never be evicted, unless the pod uses the **tolerationSeconds** parameter.

The **tolerationSeconds** parameter allows you to specify how long a pod stays bound to a node that has a node condition. If the condition still exists after the **tolerationSeconds** period, the taint remains on the node and the pods with a matching toleration are evicted. If the condition clears before the **tolerationSeconds** period, pods with matching tolerations are not removed.

If you use the **tolerationSeconds** parameter with no value, pods are never evicted because of the not ready and unreachable node conditions.



## NOTE

OpenShift Container Platform evicts pods in a rate-limited way to prevent massive pod evictions in scenarios such as the master becoming partitioned from the nodes.

By default, if more than 55% of nodes in a given zone are unhealthy, the node lifecycle controller changes that zone's state to **PartialDisruption** and the rate of pod evictions is reduced. For small clusters (by default, 50 nodes or less) in this state, nodes in this zone are not tainted and evictions are stopped.

For more information, see [Rate limits on eviction](#) in the Kubernetes documentation.

OpenShift Container Platform automatically adds a toleration for **node.kubernetes.io/not-ready** and **node.kubernetes.io/unreachable** with **tolerationSeconds=300**, unless the **Pod** configuration specifies either toleration.

```
apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: node.kubernetes.io/not-ready
    operator: Exists
    effect: NoExecute
    tolerationSeconds: 300 1
  - key: node.kubernetes.io/unreachable
    operator: Exists
    effect: NoExecute
    tolerationSeconds: 300
#...
```

- 1** These tolerations ensure that the default pod behavior is to remain bound for five minutes after one of these node conditions problems is detected.

You can configure these tolerations as needed. For example, if you have an application with a lot of local state, you might want to keep the pods bound to node for a longer time in the event of network partition, allowing for the partition to recover and avoiding pod eviction.

Pods spawned by a daemon set are created with **NoExecute** tolerations for the following taints with no **tolerationSeconds**:

- **node.kubernetes.io/unreachable**
- **node.kubernetes.io/not-ready**

As a result, daemon set pods are never evicted because of these node conditions.

### 4.6.15. Tolerating all taints

You can configure a pod to tolerate all taints by adding an **operator: "Exists"** toleration with no **key** and **values** parameters. Pods with this toleration are not removed from a node that has taints.

#### Pod spec for tolerating all taints

```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
    - operator: "Exists"
#...

```

## 4.6.2. Adding taints and tolerations

You add tolerations to pods and taints to nodes to allow the node to control which pods should or should not be scheduled on them. For existing pods and nodes, you should add the toleration to the pod first, then add the taint to the node to avoid pods being removed from the node before you can add the toleration.

### Procedure

1. Add a toleration to a pod by editing the **Pod** spec to include a **tolerations** stanza:

#### Sample pod configuration file with an Equal operator

```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
    - key: "key1" 1
      value: "value1"
      operator: "Equal"
      effect: "NoExecute"
      tolerationSeconds: 3600 2
#...

```

- 1** The toleration parameters, as described in the **Taint and toleration components** table.
- 2** The **tolerationSeconds** parameter specifies how long a pod can remain bound to a node before being evicted.

For example:

#### Sample pod configuration file with an Exists operator

```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:

```

```
- key: "key1"
  operator: "Exists" 1
  effect: "NoExecute"
  tolerationSeconds: 3600
#...
```

- 1 The **Exists** operator does not take a **value**.

This example places a taint on **node1** that has key **key1**, value **value1**, and taint effect **NoExecute**.

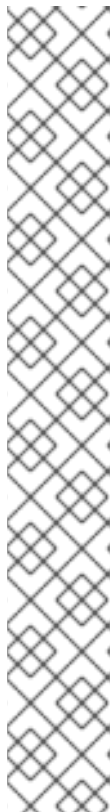
2. Add a taint to a node by using the following command with the parameters described in the **Taint and toleration components** table:

```
$ oc adm taint nodes <node_name> <key>=<value>:<effect>
```

For example:

```
$ oc adm taint nodes node1 key1=value1:NoExecute
```

This command places a taint on **node1** that has key **key1**, value **value1**, and effect **NoExecute**.



## NOTE

If you add a **NoSchedule** taint to a control plane node, the node must have the **node-role.kubernetes.io/master=:NoSchedule** taint, which is added by default.

For example:

```
apiVersion: v1
kind: Node
metadata:
  annotations:
    machine.openshift.io/machine: openshift-machine-api/ci-ln-62s7gtb-f76d1-
v8jxv-master-0
    machineconfiguration.openshift.io/currentConfig: rendered-master-
cdc1ab7da414629332cc4c3926e6e59c
  name: my-node
#...
spec:
  taints:
    - effect: NoSchedule
      key: node-role.kubernetes.io/master
#...
```

The tolerations on the pod match the taint on the node. A pod with either toleration can be scheduled onto **node1**.

### 4.6.2.1. Adding taints and tolerations using a compute machine set

You can add taints to nodes using a compute machine set. All nodes associated with the **MachineSet** object are updated with the taint. Tolerations respond to taints added by a compute machine set in the same manner as taints added directly to the nodes.



## Procedure

1. Add a toleration to a pod by editing the **Pod** spec to include a **tolerations** stanza:

### Sample pod configuration file with Equal operator

```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: "key1" 1
    value: "value1"
    operator: "Equal"
    effect: "NoExecute"
    tolerationSeconds: 3600 2
#...
```

- 1 The toleration parameters, as described in the **Taint and toleration components** table.
- 2 The **tolerationSeconds** parameter specifies how long a pod is bound to a node before being evicted.

For example:

### Sample pod configuration file with Exists operator

```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: "key1"
    operator: "Exists"
    effect: "NoExecute"
    tolerationSeconds: 3600
#...
```

2. Add the taint to the **MachineSet** object:
  - a. Edit the **MachineSet** YAML for the nodes you want to taint or you can create a new **MachineSet** object:

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

- b. Add the taint to the **spec.template.spec** section:

#### Example taint in a compute machine set specification

```
apiVersion: machine.openshift.io/v1beta1
```

```

kind: MachineSet
metadata:
  name: my-machineset
#...
spec:
#...
  template:
#...
    spec:
      taints:
        - effect: NoExecute
          key: key1
          value: value1
#...

```

This example places a taint that has the key **key1**, value **value1**, and taint effect **NoExecute** on the nodes.

- c. Scale down the compute machine set to 0:

```
$ oc scale --replicas=0 machineset <machineset> -n openshift-machine-api
```

#### TIP

You can alternatively apply the following YAML to scale the compute machine set:

```

apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  name: <machineset>
  namespace: openshift-machine-api
spec:
  replicas: 0

```

Wait for the machines to be removed.

- d. Scale up the compute machine set as needed:

```
$ oc scale --replicas=2 machineset <machineset> -n openshift-machine-api
```

Or:

```
$ oc edit machineset <machineset> -n openshift-machine-api
```

Wait for the machines to start. The taint is added to the nodes associated with the **MachineSet** object.

#### 4.6.2.2. Binding a user to a node using taints and tolerations

If you want to dedicate a set of nodes for exclusive use by a particular set of users, add a toleration to their pods. Then, add a corresponding taint to those nodes. The pods with the tolerations are allowed to use the tainted nodes or any other nodes in the cluster.

If you want ensure the pods are scheduled to only those tainted nodes, also add a label to the same set of nodes and add a node affinity to the pods so that the pods can only be scheduled onto nodes with that label.

## Procedure

To configure a node so that users can use only that node:

1. Add a corresponding taint to those nodes:

For example:

```
$ oc adm taint nodes node1 dedicated=groupName:NoSchedule
```

## TIP

You can alternatively apply the following YAML to add the taint:

```
kind: Node
apiVersion: v1
metadata:
  name: my-node
#...
spec:
  taints:
    - key: dedicated
      value: groupName
      effect: NoSchedule
#...
```

2. Add a toleration to the pods by writing a custom admission controller.

### 4.6.2.3. Creating a project with a node selector and toleration

You can create a project that uses a node selector and toleration, which are set as annotations, to control the placement of pods onto specific nodes. Any subsequent resources created in the project are then scheduled on nodes that have a taint matching the toleration.

## Prerequisites

- A label for node selection has been added to one or more nodes by using a compute machine set or editing the node directly.
- A taint has been added to one or more nodes by using a compute machine set or editing the node directly.

## Procedure

1. Create a **Project** resource definition, specifying a node selector and toleration in the **metadata.annotations** section:

### Example project.yaml file

```
kind: Project
apiVersion: project.openshift.io/v1
```

```

metadata:
  name: <project_name> ❶
  annotations:
    openshift.io/node-selector: '<label>' ❷
    scheduler.alpha.kubernetes.io/defaultTolerations: >-
      [{"operator": "Exists", "effect": "NoSchedule", "key":
        "<key_name>"} ❸
      ]

```

- ❶ The project name.
- ❷ The default node selector label.
- ❸ The toleration parameters, as described in the **Taint and toleration components** table. This example uses the **NoSchedule** effect, which allows existing pods on the node to remain, and the **Exists** operator, which does not take a value.

2. Use the **oc apply** command to create the project:

```
$ oc apply -f project.yaml
```

Any subsequent resources created in the **<project\_name>** namespace should now be scheduled on the specified nodes.

### Additional resources

- Adding taints and tolerations [manually to nodes](#) or [with compute machine sets](#)
- [Creating project-wide node selectors](#)
- [Pod placement of Operator workloads](#)

#### 4.6.2.4. Controlling nodes with special hardware using taints and tolerations

In a cluster where a small subset of nodes have specialized hardware, you can use taints and tolerations to keep pods that do not need the specialized hardware off of those nodes, leaving the nodes for pods that do need the specialized hardware. You can also require pods that need specialized hardware to use specific nodes.

You can achieve this by adding a toleration to pods that need the special hardware and tainting the nodes that have the specialized hardware.

### Procedure

To ensure nodes with specialized hardware are reserved for specific pods:

1. Add a toleration to pods that need the special hardware.  
For example:

```

apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...

```

```
spec:
  tolerations:
    - key: "disktype"
      value: "ssd"
      operator: "Equal"
      effect: "NoSchedule"
      tolerationSeconds: 3600
  #...
```

2. Taint the nodes that have the specialized hardware using one of the following commands:

```
$ oc adm taint nodes <node-name> disktype=ssd:NoSchedule
```

Or:

```
$ oc adm taint nodes <node-name> disktype=ssd:PreferNoSchedule
```

### TIP

You can alternatively apply the following YAML to add the taint:

```
kind: Node
apiVersion: v1
metadata:
  name: my_node
  #...
spec:
  taints:
    - key: disktype
      value: ssd
      effect: PreferNoSchedule
  #...
```

### 4.6.3. Removing taints and tolerations

You can remove taints from nodes and tolerations from pods as needed. You should add the toleration to the pod first, then add the taint to the node to avoid pods being removed from the node before you can add the toleration.

#### Procedure

To remove taints and tolerations:

1. To remove a taint from a node:

```
$ oc adm taint nodes <node-name> <key>-
```

For example:

```
$ oc adm taint nodes ip-10-0-132-248.ec2.internal key1-
```

#### Example output

```
node/ip-10-0-132-248.ec2.internal untainted
```

- To remove a toleration from a pod, edit the **Pod** spec to remove the toleration:

```
apiVersion: v1
kind: Pod
metadata:
  name: my-pod
#...
spec:
  tolerations:
  - key: "key2"
    operator: "Exists"
    effect: "NoExecute"
    tolerationSeconds: 3600
#...
```

## 4.7. PLACING PODS ON SPECIFIC NODES USING NODE SELECTORS

A *node selector* specifies a map of key/value pairs that are defined using custom labels on nodes and selectors specified in pods.

For the pod to be eligible to run on a node, the pod must have the same key/value node selector as the label on the node.

### 4.7.1. About node selectors

You can use node selectors on pods and labels on nodes to control where the pod is scheduled. With node selectors, OpenShift Container Platform schedules the pods on nodes that contain matching labels.

You can use a node selector to place specific pods on specific nodes, cluster-wide node selectors to place new pods on specific nodes anywhere in the cluster, and project node selectors to place new pods in a project on specific nodes.

For example, as a cluster administrator, you can create an infrastructure where application developers can deploy pods only onto the nodes closest to their geographical location by including a node selector in every pod they create. In this example, the cluster consists of five data centers spread across two regions. In the U.S., label the nodes as **us-east**, **us-central**, or **us-west**. In the Asia-Pacific region (APAC), label the nodes as **apac-east** or **apac-west**. The developers can add a node selector to the pods they create to ensure the pods get scheduled on those nodes.

A pod is not scheduled if the **Pod** object contains a node selector, but no node has a matching label.



## IMPORTANT

If you are using node selectors and node affinity in the same pod configuration, the following rules control pod placement onto nodes:

- If you configure both **nodeSelector** and **nodeAffinity**, both conditions must be satisfied for the pod to be scheduled onto a candidate node.
- If you specify multiple **nodeSelectorTerms** associated with **nodeAffinity** types, then the pod can be scheduled onto a node if one of the **nodeSelectorTerms** is satisfied.
- If you specify multiple **matchExpressions** associated with **nodeSelectorTerms**, then the pod can be scheduled onto a node only if all **matchExpressions** are satisfied.

### Node selectors on specific pods and nodes

You can control which node a specific pod is scheduled on by using node selectors and labels.

To use node selectors and labels, first label the node to avoid pods being descheduled, then add the node selector to the pod.



## NOTE

You cannot add a node selector directly to an existing scheduled pod. You must label the object that controls the pod, such as deployment config.

For example, the following **Node** object has the **region: east** label:

### Sample Node object with a label

```
kind: Node
apiVersion: v1
metadata:
  name: ip-10-0-131-14.ec2.internal
  selfLink: /api/v1/nodes/ip-10-0-131-14.ec2.internal
  uid: 7bc2580a-8b8e-11e9-8e01-021ab4174c74
  resourceVersion: '478704'
  creationTimestamp: '2019-06-10T14:46:08Z'
  labels:
    kubernetes.io/os: linux
    topology.kubernetes.io/zone: us-east-1a
    node.openshift.io/os_version: '4.5'
    node-role.kubernetes.io/worker: ""
    topology.kubernetes.io/region: us-east-1
    node.openshift.io/os_id: rhcos
    node.kubernetes.io/instance-type: m4.large
    kubernetes.io/hostname: ip-10-0-131-14
    kubernetes.io/arch: amd64
    region: east 1
    type: user-node
#...
```

**1** Labels to match the pod node selector.

A pod has the **type: user-node,region: east** node selector:

### Sample Pod object with node selectors

```
apiVersion: v1
kind: Pod
metadata:
  name: s1
#...
spec:
  nodeSelector: 1
    region: east
    type: user-node
#...
```

1 Node selectors to match the node label. The node must have a label for each node selector.

When you create the pod using the example pod spec, it can be scheduled on the example node.

### Default cluster-wide node selectors

With default cluster-wide node selectors, when you create a pod in that cluster, OpenShift Container Platform adds the default node selectors to the pod and schedules the pod on nodes with matching labels.

For example, the following **Scheduler** object has the default cluster-wide **region=east** and **type=user-node** node selectors:

### Example Scheduler Operator Custom Resource

```
apiVersion: config.openshift.io/v1
kind: Scheduler
metadata:
  name: cluster
#...
spec:
  defaultNodeSelector: type=user-node,region=east
#...
```

A node in that cluster has the **type=user-node,region=east** labels:

### Example Node object

```
apiVersion: v1
kind: Node
metadata:
  name: ci-ln-qg1il3k-f76d1-hlmhl-worker-b-df2s4
#...
labels:
  region: east
  type: user-node
#...
```

### Example Pod object with a node selector

-



```

apiVersion: v1
kind: Pod
metadata:
  name: s1
#...
spec:
  nodeSelector:
    region: east
#...

```

When you create the pod using the example pod spec in the example cluster, the pod is created with the cluster-wide node selector and is scheduled on the labeled node:

### Example pod list with the pod on the labeled node

```

NAME          READY  STATUS   RESTARTS  AGE  IP           NODE
NOMINATED    NODE  READINESS GATES
pod-s1        1/1    Running  0          20s  10.131.2.6  ci-ln-qg1il3k-f76d1-hlmhl-worker-b-df2s4
<none>       <none>

```



#### NOTE

If the project where you create the pod has a project node selector, that selector takes preference over a cluster-wide node selector. Your pod is not created or scheduled if the pod does not have the project node selector.

### Project node selectors

With project node selectors, when you create a pod in this project, OpenShift Container Platform adds the node selectors to the pod and schedules the pods on a node with matching labels. If there is a cluster-wide default node selector, a project node selector takes preference.

For example, the following project has the **region=east** node selector:

### Example Namespace object

```

apiVersion: v1
kind: Namespace
metadata:
  name: east-region
  annotations:
    openshift.io/node-selector: "region=east"
#...

```

The following node has the **type=user-node,region=east** labels:

### Example Node object

```

apiVersion: v1
kind: Node
metadata:
  name: ci-ln-qg1il3k-f76d1-hlmhl-worker-b-df2s4
#...
  labels:

```

```

    region: east
    type: user-node
  #...

```

When you create the pod using the example pod spec in this example project, the pod is created with the project node selectors and is scheduled on the labeled node:

### Example Pod object

```

apiVersion: v1
kind: Pod
metadata:
  namespace: east-region
  #...
spec:
  nodeSelector:
    region: east
    type: user-node
  #...

```

### Example pod list with the pod on the labeled node

```

NAME          READY   STATUS    RESTARTS   AGE   IP           NODE
NOMINATED NODE READINESS GATES
pod-s1        1/1     Running   0           20s   10.131.2.6   ci-ln-qg1il3k-f76d1-hlmhl-worker-b-df2s4
<none>       <none>

```

A pod in the project is not created or scheduled if the pod contains different node selectors. For example, if you deploy the following pod into the example project, it is not be created:

### Example Pod object with an invalid node selector

```

apiVersion: v1
kind: Pod
metadata:
  name: west-region
  #...
spec:
  nodeSelector:
    region: west
  #...

```

## 4.7.2. Using node selectors to control pod placement

You can use node selectors on pods and labels on nodes to control where the pod is scheduled. With node selectors, OpenShift Container Platform schedules the pods on nodes that contain matching labels.

You add labels to a node, a compute machine set, or a machine config. Adding the label to the compute machine set ensures that if the node or machine goes down, new nodes have the label. Labels added to a node or machine config do not persist if the node or machine goes down.

To add node selectors to an existing pod, add a node selector to the controlling object for that pod, such

as a **ReplicaSet** object, **DaemonSet** object, **StatefulSet** object, **Deployment** object, or **DeploymentConfig** object. Any existing pods under that controlling object are recreated on a node with a matching label. If you are creating a new pod, you can add the node selector directly to the pod spec. If the pod does not have a controlling object, you must delete the pod, edit the pod spec, and recreate the pod.



## NOTE

You cannot add a node selector directly to an existing scheduled pod.

## Prerequisites

To add a node selector to existing pods, determine the controlling object for that pod. For example, the **router-default-66d5cf9464-m2g75** pod is controlled by the **router-default-66d5cf9464** replica set:

```
$ oc describe pod router-default-66d5cf9464-7pwkc
```

## Example output

```
kind: Pod
apiVersion: v1
metadata:
# ...
Name:          router-default-66d5cf9464-7pwkc
Namespace:     openshift-ingress
# ...
Controlled By: ReplicaSet/router-default-66d5cf9464
# ...
```

The web console lists the controlling object under **ownerReferences** in the pod YAML:

```
apiVersion: v1
kind: Pod
metadata:
  name: router-default-66d5cf9464-7pwkc
# ...
ownerReferences:
- apiVersion: apps/v1
  kind: ReplicaSet
  name: router-default-66d5cf9464
  uid: d81dd094-da26-11e9-a48a-128e7edf0312
  controller: true
  blockOwnerDeletion: true
# ...
```

## Procedure

1. Add labels to a node by using a compute machine set or editing the node directly:
  - Use a **MachineSet** object to add labels to nodes managed by the compute machine set when a node is created:
    - a. Run the following command to add labels to a **MachineSet** object:

```
$ oc patch MachineSet <name> --type='json' -
p=[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"<key>="
<value>","<key>="<value>"}]}] -n openshift-machine-api
```

For example:

```
$ oc patch MachineSet abc612-msrtw-worker-us-east-1c --type='json' -
p=[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"type":"user-
node","region":"east"}}] -n openshift-machine-api
```

## TIP

You can alternatively apply the following YAML to add labels to a compute machine set:

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  name: xf2bd-infra-us-east-2a
  namespace: openshift-machine-api
spec:
  template:
    spec:
      metadata:
        labels:
          region: "east"
          type: "user-node"
# ...
```

- b. Verify that the labels are added to the **MachineSet** object by using the **oc edit** command:

For example:

```
$ oc edit MachineSet abc612-msrtw-worker-us-east-1c -n openshift-machine-api
```

## Example MachineSet object

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
# ...
spec:
# ...
  template:
    metadata:
# ...
    spec:
      metadata:
        labels:
          region: east
          type: user-node
# ...
```

- Add labels directly to a node:
  - a. Edit the **Node** object for the node:

```
$ oc label nodes <name> <key>=<value>
```

For example, to label a node:

```
$ oc label nodes ip-10-0-142-25.ec2.internal type=user-node region=east
```

### TIP

You can alternatively apply the following YAML to add labels to a node:

```
kind: Node
apiVersion: v1
metadata:
  name: hello-node-6fbccf8d9
  labels:
    type: "user-node"
    region: "east"
# ...
```

- b. Verify that the labels are added to the node:

```
$ oc get nodes -l type=user-node,region=east
```

### Example output

```
NAME                                STATUS ROLES AGE VERSION
ip-10-0-142-25.ec2.internal Ready worker 17m v1.30.3
```

2. Add the matching node selector to a pod:

- To add a node selector to existing and future pods, add a node selector to the controlling object for the pods:

### Example ReplicaSet object with labels

```
kind: ReplicaSet
apiVersion: apps/v1
metadata:
  name: hello-node-6fbccf8d9
# ...
spec:
# ...
template:
  metadata:
    creationTimestamp: null
  labels:
    ingresscontroller.operator.openshift.io/deployment-ingresscontroller: default
    pod-template-hash: 66d5cf9464
  spec:
```

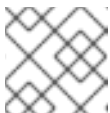
```
nodeSelector:
  kubernetes.io/os: linux
  node-role.kubernetes.io/worker: "
  type: user-node 1
# ...
```

- 1 Add the node selector.

- To add a node selector to a specific, new pod, add the selector to the **Pod** object directly:

#### Example Pod object with a node selector

```
apiVersion: v1
kind: Pod
metadata:
  name: hello-node-6fbccf8d9
# ...
spec:
  nodeSelector:
    region: east
    type: user-node
# ...
```



#### NOTE

You cannot add a node selector directly to an existing scheduled pod.

### 4.7.3. Creating default cluster-wide node selectors

You can use default cluster-wide node selectors on pods together with labels on nodes to constrain all pods created in a cluster to specific nodes.

With cluster-wide node selectors, when you create a pod in that cluster, OpenShift Container Platform adds the default node selectors to the pod and schedules the pod on nodes with matching labels.

You configure cluster-wide node selectors by editing the Scheduler Operator custom resource (CR). You add labels to a node, a compute machine set, or a machine config. Adding the label to the compute machine set ensures that if the node or machine goes down, new nodes have the label. Labels added to a node or machine config do not persist if the node or machine goes down.



#### NOTE

You can add additional key/value pairs to a pod. But you cannot add a different value for a default key.

#### Procedure

To add a default cluster-wide node selector:

1. Edit the Scheduler Operator CR to add the default cluster-wide node selectors:

```
$ oc edit scheduler cluster
```

## Example Scheduler Operator CR with a node selector

```

apiVersion: config.openshift.io/v1
kind: Scheduler
metadata:
  name: cluster
...
spec:
  defaultNodeSelector: type=user-node,region=east 1
  mastersSchedulable: false

```

- 1** Add a node selector with the appropriate **<key>:<value>** pairs.

After making this change, wait for the pods in the **openshift-kube-apiserver** project to redeploy. This can take several minutes. The default cluster-wide node selector does not take effect until the pods redeploy.

2. Add labels to a node by using a compute machine set or editing the node directly:
  - Use a compute machine set to add labels to nodes managed by the compute machine set when a node is created:
    - a. Run the following command to add labels to a **MachineSet** object:

```

$ oc patch MachineSet <name> --type='json' -
p='[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"<key>":"<value>","<key>":"<value>"},"<key>":"<value>"}]' -n openshift-machine-api 1

```

- 1** Add a **<key>/<value>** pair for each label.

For example:

```

$ oc patch MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c --type='json' -
p='[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"type":"user-node","region":"east"}}]' -n openshift-machine-api

```

### TIP

You can alternatively apply the following YAML to add labels to a compute machine set:

```

apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  name: <machineset>
  namespace: openshift-machine-api
spec:
  template:
    spec:
      metadata:
        labels:
          region: "east"
          type: "user-node"

```

- b. Verify that the labels are added to the **MachineSet** object by using the **oc edit** command:  
For example:

```
$ oc edit MachineSet abc612-msrtw-worker-us-east-1c -n openshift-machine-api
```

### Example MachineSet object

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
...
spec:
...
template:
  metadata:
...
  spec:
    metadata:
      labels:
        region: east
        type: user-node
...

```

- c. Redeploy the nodes associated with that compute machine set by scaling down to **0** and scaling up the nodes:  
For example:

```
$ oc scale --replicas=0 MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c -n openshift-machine-api
```

```
$ oc scale --replicas=1 MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c -n openshift-machine-api
```

- d. When the nodes are ready and available, verify that the label is added to the nodes by using the **oc get** command:

```
$ oc get nodes -l <key>=<value>
```

For example:

```
$ oc get nodes -l type=user-node
```

### Example output

```
NAME                                STATUS ROLES  AGE  VERSION
ci-ln-l8nry52-f76d1-hl7m7-worker-c-vmqzp Ready  worker  61s  v1.30.3
```

- Add labels directly to a node:
  - a. Edit the **Node** object for the node:

```
$ oc label nodes <name> <key>=<value>
```



For example, to label a node:

```
$ oc label nodes ci-ln-l8nry52-f76d1-hl7m7-worker-b-tgq49 type=user-node
region=east
```

### TIP

You can alternatively apply the following YAML to add labels to a node:

```
kind: Node
apiVersion: v1
metadata:
  name: <node_name>
labels:
  type: "user-node"
  region: "east"
```

- b. Verify that the labels are added to the node using the **oc get** command:

```
$ oc get nodes -l <key>=<value>,<key>=<value>
```

For example:

```
$ oc get nodes -l type=user-node,region=east
```

### Example output

```
NAME                                STATUS ROLES  AGE  VERSION
ci-ln-l8nry52-f76d1-hl7m7-worker-b-tgq49  Ready  worker  17m  v1.30.3
```

## 4.7.4. Creating project-wide node selectors

You can use node selectors in a project together with labels on nodes to constrain all pods created in that project to the labeled nodes.

When you create a pod in this project, OpenShift Container Platform adds the node selectors to the pods in the project and schedules the pods on a node with matching labels in the project. If there is a cluster-wide default node selector, a project node selector takes preference.

You add node selectors to a project by editing the **Namespace** object to add the **openshift.io/node-selector** parameter. You add labels to a node, a compute machine set, or a machine config. Adding the label to the compute machine set ensures that if the node or machine goes down, new nodes have the label. Labels added to a node or machine config do not persist if the node or machine goes down.

A pod is not scheduled if the **Pod** object contains a node selector, but no project has a matching node selector. When you create a pod from that spec, you receive an error similar to the following message:

### Example error message

```
Error from server (Forbidden): error when creating "pod.yaml": pods "pod-4" is forbidden: pod node
label selector conflicts with its project node label selector
```



## NOTE

You can add additional key/value pairs to a pod. But you cannot add a different value for a project key.

## Procedure

To add a default project node selector:

1. Create a namespace or edit an existing namespace to add the **openshift.io/node-selector** parameter:

```
$ oc edit namespace <name>
```

## Example output

```
apiVersion: v1
kind: Namespace
metadata:
  annotations:
    openshift.io/node-selector: "type=user-node,region=east" 1
    openshift.io/description: ""
    openshift.io/display-name: ""
    openshift.io/requester: kube:admin
    openshift.io/sa.scc.mcs: s0:c30,c5
    openshift.io/sa.scc.supplemental-groups: 1000880000/10000
    openshift.io/sa.scc.uid-range: 1000880000/10000
  creationTimestamp: "2021-05-10T12:35:04Z"
  labels:
    kubernetes.io/metadata.name: demo
  name: demo
  resourceVersion: "145537"
  uid: 3f8786e3-1fcb-42e3-a0e3-e2ac54d15001
spec:
  finalizers:
    - kubernetes
```

- 1 Add the **openshift.io/node-selector** with the appropriate **<key>:<value>** pairs.

2. Add labels to a node by using a compute machine set or editing the node directly:

- Use a **MachineSet** object to add labels to nodes managed by the compute machine set when a node is created:

- a. Run the following command to add labels to a **MachineSet** object:

```
$ oc patch MachineSet <name> --type='json' -
p='[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"<key>="
<value>","<key>="<value>"}}]' -n openshift-machine-api
```

For example:

```
$ oc patch MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c --type='json' -
p=[{"op":"add","path":"/spec/template/spec/metadata/labels", "value":{"type":"user-
node", "region":"east"}}] -n openshift-machine-api
```

## TIP

You can alternatively apply the following YAML to add labels to a compute machine set:

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  name: <machineset>
  namespace: openshift-machine-api
spec:
  template:
    spec:
      metadata:
        labels:
          region: "east"
          type: "user-node"
```

- b. Verify that the labels are added to the **MachineSet** object by using the **oc edit** command:  
For example:

```
$ oc edit MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c -n openshift-machine-api
```

## Example output

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
...
spec:
...
  template:
    metadata:
...
    spec:
      metadata:
        labels:
          region: east
          type: user-node
```

- c. Redeploy the nodes associated with that compute machine set:  
For example:

```
$ oc scale --replicas=0 MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c -n openshift-
machine-api
```

```
$ oc scale --replicas=1 MachineSet ci-ln-l8nry52-f76d1-hl7m7-worker-c -n openshift-
machine-api
```

- d. When the nodes are ready and available, verify that the label is added to the nodes by using the **oc get** command:

```
$ oc get nodes -l <key>=<value>
```

For example:

```
$ oc get nodes -l type=user-node,region=east
```

### Example output

```
NAME                                STATUS ROLES  AGE  VERSION
ci-ln-l8nry52-f76d1-hl7m7-worker-c-vmqzp Ready  worker  61s  v1.30.3
```

- Add labels directly to a node:
  - a. Edit the **Node** object to add labels:

```
$ oc label <resource> <name> <key>=<value>
```

For example, to label a node:

```
$ oc label nodes ci-ln-l8nry52-f76d1-hl7m7-worker-c-tgq49 type=user-node
region=east
```

### TIP

You can alternatively apply the following YAML to add labels to a node:

```
kind: Node
apiVersion: v1
metadata:
  name: <node_name>
labels:
  type: "user-node"
  region: "east"
```

- b. Verify that the labels are added to the **Node** object using the **oc get** command:

```
$ oc get nodes -l <key>=<value>
```

For example:

```
$ oc get nodes -l type=user-node,region=east
```

### Example output

```
NAME                                STATUS ROLES  AGE  VERSION
ci-ln-l8nry52-f76d1-hl7m7-worker-b-tgq49 Ready  worker  17m  v1.30.3
```

- [Creating a project with a node selector and toleration](#)

## 4.8. CONTROLLING POD PLACEMENT BY USING POD TOPOLOGY SPREAD CONSTRAINTS

You can use pod topology spread constraints to provide fine-grained control over the placement of your pods across nodes, zones, regions, or other user-defined topology domains. Distributing pods across failure domains can help to achieve high availability and more efficient resource utilization.

### 4.8.1. Example use cases

- As an administrator, I want my workload to automatically scale between two to fifteen pods. I want to ensure that when there are only two pods, they are not placed on the same node, to avoid a single point of failure.
- As an administrator, I want to distribute my pods evenly across multiple infrastructure zones to reduce latency and network costs. I want to ensure that my cluster can self-heal if issues arise.

### 4.8.2. Important considerations

- Pods in an OpenShift Container Platform cluster are managed by *workload controllers* such as deployments, stateful sets, or daemon sets. These controllers define the desired state for a group of pods, including how they are distributed and scaled across the nodes in the cluster. You should set the same pod topology spread constraints on all pods in a group to avoid confusion. When using a workload controller, such as a deployment, the pod template typically handles this for you.
- Mixing different pod topology spread constraints can make OpenShift Container Platform behavior confusing and troubleshooting more difficult. You can avoid this by ensuring that all nodes in a topology domain are consistently labeled. OpenShift Container Platform automatically populates well-known labels, such as **kubernetes.io/hostname**. This helps avoid the need for manual labeling of nodes. These labels provide essential topology information, ensuring consistent node labeling across the cluster.
- Only pods within the same namespace are matched and grouped together when spreading due to a constraint.
- You can specify multiple pod topology spread constraints, but you must ensure that they do not conflict with each other. All pod topology spread constraints must be satisfied for a pod to be placed.

### 4.8.3. Understanding skew and maxSkew

Skew refers to the difference in the number of pods that match a specified label selector across different topology domains, such as zones or nodes.

The skew is calculated for each domain by taking the absolute difference between the number of pods in that domain and the number of pods in the domain with the lowest amount of pods scheduled. Setting a **maxSkew** value guides the scheduler to maintain a balanced pod distribution.

#### 4.8.3.1. Example skew calculation

You have three zones (A, B, and C), and you want to distribute your pods evenly across these zones. If zone A has 5 pods, zone B has 3 pods, and zone C has 2 pods, to find the skew, you can subtract the

number of pods in the domain with the lowest amount of pods scheduled from the number of pods currently in each zone. This means that the skew for zone A is 3, the skew for zone B is 1, and the skew for zone C is 0.

#### 4.8.3.2. The `maxSkew` parameter

The **`maxSkew`** parameter defines the maximum allowable difference, or skew, in the number of pods between any two topology domains. If **`maxSkew`** is set to **1**, the number of pods in any topology domain should not differ by more than 1 from any other domain. If the skew exceeds **`maxSkew`**, the scheduler attempts to place new pods in a way that reduces the skew, adhering to the constraints.

Using the previous example skew calculation, the skew values exceed the default **`maxSkew`** value of **1**. The scheduler places new pods in zone B and zone C to reduce the skew and achieve a more balanced distribution, ensuring that no topology domain exceeds the skew of 1.

#### 4.8.4. Example configurations for pod topology spread constraints

You can specify which pods to group together, which topology domains they are spread among, and the acceptable skew.

The following examples demonstrate pod topology spread constraint configurations.

##### Example to distribute pods that match the specified labels based on their zone

```
apiVersion: v1
kind: Pod
metadata:
  name: my-pod
  labels:
    region: us-east
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  topologySpreadConstraints:
  - maxSkew: 1 1
    topologyKey: topology.kubernetes.io/zone 2
    whenUnsatisfiable: DoNotSchedule 3
    labelSelector: 4
      matchLabels:
        region: us-east 5
    matchLabelKeys:
    - my-pod-label 6
  containers:
  - image: "docker.io/ocpqe/hello-pod"
    name: hello-pod
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
```

- 1** The maximum difference in number of pods between any two topology domains. The default is **1**, and you cannot specify a value of **0**.

- 2 The key of a node label. Nodes with this key and identical value are considered to be in the same topology.
- 3 How to handle a pod if it does not satisfy the spread constraint. The default is **DoNotSchedule**, which tells the scheduler not to schedule the pod. Set to **ScheduleAnyway** to still schedule the pod, but the scheduler prioritizes honoring the skew to not make the cluster more imbalanced.
- 4 Pods that match this label selector are counted and recognized as a group when spreading to satisfy the constraint. Be sure to specify a label selector, otherwise no pods can be matched.
- 5 Be sure that this **Pod** spec also sets its labels to match this label selector if you want it to be counted properly in the future.
- 6 A list of pod label keys to select which pods to calculate spreading over.

### Example demonstrating a single pod topology spread constraint

```

kind: Pod
apiVersion: v1
metadata:
  name: my-pod
  labels:
    region: us-east
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  topologySpreadConstraints:
  - maxSkew: 1
    topologyKey: topology.kubernetes.io/zone
    whenUnsatisfiable: DoNotSchedule
    labelSelector:
      matchLabels:
        region: us-east
  containers:
  - image: "docker.io/ocpqe/hello-pod"
    name: hello-pod
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]

```

The previous example defines a **Pod** spec with a one pod topology spread constraint. It matches on pods labeled **region: us-east**, distributes among zones, specifies a skew of **1**, and does not schedule the pod if it does not meet these requirements.

### Example demonstrating multiple pod topology spread constraints

```

kind: Pod
apiVersion: v1
metadata:
  name: my-pod-2
  labels:
    region: us-east

```

```

spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  topologySpreadConstraints:
  - maxSkew: 1
    topologyKey: node
    whenUnsatisfiable: DoNotSchedule
    labelSelector:
      matchLabels:
        region: us-east
  - maxSkew: 1
    topologyKey: rack
    whenUnsatisfiable: DoNotSchedule
    labelSelector:
      matchLabels:
        region: us-east
  containers:
  - image: "docker.io/ocpqe/hello-pod"
    name: hello-pod
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]

```

The previous example defines a **Pod** spec with two pod topology spread constraints. Both match on pods labeled **region: us-east**, specify a skew of **1**, and do not schedule the pod if it does not meet these requirements.

The first constraint distributes pods based on a user-defined label **node**, and the second constraint distributes pods based on a user-defined label **rack**. Both constraints must be met for the pod to be scheduled.

#### 4.8.5. Additional resources

- [Understanding how to update labels on nodes](#)

## 4.9. DESCHEDULER

### 4.9.1. Descheduler overview

While the [scheduler](#) is used to determine the most suitable node to host a new pod, the descheduler can be used to evict a running pod so that the pod can be rescheduled onto a more suitable node.



#### IMPORTANT

The Kube Descheduler Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.

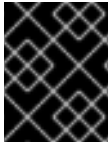
#### 4.9.1.1. About the descheduler

You can use the descheduler to evict pods based on specific strategies so that the pods can be rescheduled onto more appropriate nodes.



You can benefit from descheduling running pods in situations such as the following:

- Nodes are underutilized or overutilized.
- Pod and node affinity requirements, such as taints or labels, have changed and the original scheduling decisions are no longer appropriate for certain nodes.
- Node failure requires pods to be moved.
- New nodes are added to clusters.
- Pods have been restarted too many times.



### IMPORTANT

The descheduler does not schedule replacement of evicted pods. The scheduler automatically performs this task for the evicted pods.

When the descheduler decides to evict pods from a node, it employs the following general mechanism:

- Pods in the **openshift-\*** and **kube-system** namespaces are never evicted.
- Critical pods with **priorityClassName** set to **system-cluster-critical** or **system-node-critical** are never evicted.
- Static, mirrored, or stand-alone pods that are not part of a replication controller, replica set, deployment, or job are never evicted because these pods will not be recreated.
- Pods associated with daemon sets are never evicted.
- Pods with local storage are never evicted.
- Best effort pods are evicted before burstable and guaranteed pods.
- All types of pods with the **descheduler.alpha.kubernetes.io/evict** annotation are eligible for eviction. This annotation is used to override checks that prevent eviction, and the user can select which pod is evicted. Users should know how and if the pod will be recreated.
- Pods subject to pod disruption budget (PDB) are not evicted if descheduling violates its pod disruption budget (PDB). The pods are evicted by using eviction subresource to handle PDB.

#### 4.9.1.2. Descheduler profiles

The following descheduler profiles are available:

##### AffinityAndTaints

This profile evicts pods that violate inter-pod anti-affinity, node affinity, and node taints.

It enables the following strategies:

- **RemovePodsViolatingInterPodAntiAffinity**: removes pods that are violating inter-pod anti-affinity.
- **RemovePodsViolatingNodeAffinity**: removes pods that are violating node affinity.
- **RemovePodsViolatingNodeTaints**: removes pods that are violating **NoSchedule** taints on nodes.

Pods with a node affinity type of **requiredDuringSchedulingIgnoredDuringExecution** are removed.

### TopologyAndDuplicates

This profile evicts pods in an effort to evenly spread similar pods, or pods of the same topology domain, among nodes.

It enables the following strategies:

- **RemovePodsViolatingTopologySpreadConstraint:** finds unbalanced topology domains and tries to evict pods from larger ones when **DoNotSchedule** constraints are violated.
- **RemoveDuplicates:** ensures that there is only one pod associated with a replica set, replication controller, deployment, or job running on same node. If there are more, those duplicate pods are evicted for better pod distribution in a cluster.

### LifecycleAndUtilization

This profile evicts long-running pods and balances resource usage between nodes.

It enables the following strategies:

- **RemovePodsHavingTooManyRestarts:** removes pods whose containers have been restarted too many times.  
Pods where the sum of restarts over all containers (including Init Containers) is more than 100.
- **LowNodeUtilization:** finds nodes that are underutilized and evicts pods, if possible, from overutilized nodes in the hope that recreation of evicted pods will be scheduled on these underutilized nodes.  
A node is considered underutilized if its usage is below 20% for all thresholds (CPU, memory, and number of pods).  
  
A node is considered overutilized if its usage is above 50% for any of the thresholds (CPU, memory, and number of pods).
- **PodLifeTime:** evicts pods that are too old.  
By default, pods that are older than 24 hours are removed. You can customize the pod lifetime value.

### SoftTopologyAndDuplicates

This profile is the same as **TopologyAndDuplicates**, except that pods with soft topology constraints, such as **whenUnsatisfiable: ScheduleAnyway**, are also considered for eviction.



#### NOTE

Do not enable both **SoftTopologyAndDuplicates** and **TopologyAndDuplicates**. Enabling both results in a conflict.

### EvictPodsWithLocalStorage

This profile allows pods with local storage to be eligible for eviction.

### EvictPodsWithPVC

This profile allows pods with persistent volume claims to be eligible for eviction. If you are using **Kubernetes NFS Subdir External Provisioner**, you must add an excluded namespace for the namespace where the provisioner is installed.

## 4.9.2. Kube Descheduler Operator release notes

The Kube Descheduler Operator allows you to evict pods so that they can be rescheduled on more appropriate nodes.

These release notes track the development of the Kube Descheduler Operator.



### IMPORTANT

The Kube Descheduler Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.

For more information, see [About the descheduler](#).

## 4.9.3. Evicting pods using the descheduler

You can run the descheduler in OpenShift Container Platform by installing the Kube Descheduler Operator and setting the desired profiles and other customizations.



### IMPORTANT

The Kube Descheduler Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.

### 4.9.3.1. Installing the descheduler

The descheduler is not available by default. To enable the descheduler, you must install the Kube Descheduler Operator from OperatorHub and enable one or more descheduler profiles.

By default, the descheduler runs in predictive mode, which means that it only simulates pod evictions. You must change the mode to automatic for the descheduler to perform the pod evictions.



### IMPORTANT

If you have enabled hosted control planes in your cluster, set a custom priority threshold to lower the chance that pods in the hosted control plane namespaces are evicted. Set the priority threshold class name to **hypershift-control-plane**, because it has the lowest priority value (**100000000**) of the hosted control plane priority classes.

### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- Access to the OpenShift Container Platform web console.

### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Create the required namespace for the Kube Descheduler Operator.
  - a. Navigate to **Administration** → **Namespaces** and click **Create Namespace**.

- b. Enter **openshift-kube-descheduler-operator** in the **Name** field, enter **openshift.io/cluster-monitoring=true** in the **Labels** field to enable descheduler metrics, and click **Create**.
3. Install the Kube Descheduler Operator.
  - a. Navigate to **Operators** → **OperatorHub**.
  - b. Type **Kube Descheduler Operator** into the filter box.
  - c. Select the **Kube Descheduler Operator** and click **Install**.
  - d. On the **Install Operator** page, select **A specific namespace on the cluster** Select **openshift-kube-descheduler-operator** from the drop-down menu.
  - e. Adjust the values for the **Update Channel** and **Approval Strategy** to the desired values.
  - f. Click **Install**.
4. Create a descheduler instance.
  - a. From the **Operators** → **Installed Operators** page, click the **Kube Descheduler Operator**.
  - b. Select the **Kube Descheduler** tab and click **Create KubeDescheduler**.
  - c. Edit the settings as necessary.
    - i. To evict pods instead of simulating the evictions, change the **Mode** field to **Automatic**.

#### 4.9.3.2. Configuring descheduler profiles

You can configure which profiles the descheduler uses to evict pods.

##### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.

##### Procedure

1. Edit the **KubeDescheduler** object:

```
$ oc edit kubedeschedulers.operator.openshift.io cluster -n openshift-kube-descheduler-operator
```

2. Specify one or more profiles in the **spec.profiles** section.

```
apiVersion: operator.openshift.io/v1
kind: KubeDescheduler
metadata:
  name: cluster
  namespace: openshift-kube-descheduler-operator
spec:
  deschedulingIntervalSeconds: 3600
  logLevel: Normal
  managementState: Managed
  operatorLogLevel: Normal
```

```

mode: Predictive 1
profileCustomizations:
  namespaces: 2
    excluded:
      - my-namespace
  podLifetime: 48h 3
  thresholdPriorityClassName: my-priority-class-name 4
profiles: 5
  - AffinityAndTaints
  - TopologyAndDuplicates 6
  - LifecycleAndUtilization
  - EvictPodsWithLocalStorage
  - EvictPodsWithPVC

```

- 1 Optional: By default, the descheduler does not evict pods. To evict pods, set **mode** to **Automatic**.
- 2 Optional: Set a list of user-created namespaces to include or exclude from descheduler operations. Use **excluded** to set a list of namespaces to exclude or use **included** to set a list of namespaces to include. Note that protected namespaces (**openshift-\***, **kube-system**, **hypershift**) are excluded by default.
- 3 Optional: Enable a custom pod lifetime value for the **LifecycleAndUtilization** profile. Valid units are **s**, **m**, or **h**. The default pod lifetime is 24 hours.
- 4 Optional: Specify a priority threshold to consider pods for eviction only if their priority is lower than the specified level. Use the **thresholdPriority** field to set a numerical priority threshold (for example, **10000**) or use the **thresholdPriorityClassName** field to specify a certain priority class name (for example, **my-priority-class-name**). If you specify a priority class name, it must already exist or the descheduler will throw an error. Do not set both **thresholdPriority** and **thresholdPriorityClassName**.
- 5 Add one or more profiles to enable. Available profiles: **AffinityAndTaints**, **TopologyAndDuplicates**, **LifecycleAndUtilization**, **SoftTopologyAndDuplicates**, **EvictPodsWithLocalStorage**, and **EvictPodsWithPVC**.
- 6 Do not enable both **TopologyAndDuplicates** and **SoftTopologyAndDuplicates**. Enabling both results in a conflict.

You can enable multiple profiles; the order that the profiles are specified in is not important.

3. Save the file to apply the changes.

#### 4.9.3.3. Configuring the descheduler interval

You can configure the amount of time between descheduler runs. The default is 3600 seconds (one hour).

#### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.

#### Procedure

1. Edit the **KubeDescheduler** object:

```
$ oc edit kubedeschedulers.operator.openshift.io cluster -n openshift-kube-descheduler-operator
```

2. Update the **deschedulingIntervalSeconds** field to the desired value:

```
apiVersion: operator.openshift.io/v1
kind: KubeDescheduler
metadata:
  name: cluster
  namespace: openshift-kube-descheduler-operator
spec:
  deschedulingIntervalSeconds: 3600 1
  ...
```

- 1** Set the number of seconds between descheduler runs. A value of **0** in this field runs the descheduler once and exits.

3. Save the file to apply the changes.

#### 4.9.4. Uninstalling the Kube Descheduler Operator

You can remove the Kube Descheduler Operator from OpenShift Container Platform by uninstalling the Operator and removing its related resources.



#### IMPORTANT

The Kube Descheduler Operator is not currently available for OpenShift Container Platform 4.17. The Operator is planned to be released in the near future.

##### 4.9.4.1. Uninstalling the descheduler





You can remove the descheduler from your cluster by removing the descheduler instance and uninstalling the Kube Descheduler Operator. This procedure also cleans up the **KubeDescheduler** CRD and **openshift-kube-descheduler-operator** namespace.

#### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- Access to the OpenShift Container Platform web console.

#### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Delete the descheduler instance.
  - a. From the **Operators** → **Installed Operators** page, click **Kube Descheduler Operator**.
  - b. Select the **Kube Descheduler** tab.

- c. Click the Options menu  next to the **cluster** entry and select **Delete KubeDescheduler**.
    - d. In the confirmation dialog, click **Delete**.
3. Uninstall the Kube Descheduler Operator.
  - a. Navigate to **Operators** → **Installed Operators**.
  - b. Click the Options menu  next to the **Kube Descheduler Operator** entry and select **Uninstall Operator**.
  - c. In the confirmation dialog, click **Uninstall**.
4. Delete the **openshift-kube-descheduler-operator** namespace.
  - a. Navigate to **Administration** → **Namespaces**.
  - b. Enter **openshift-kube-descheduler-operator** into the filter box.
  - c. Click the Options menu  next to the **openshift-kube-descheduler-operator** entry and select **Delete Namespace**.
  - d. In the confirmation dialog, enter **openshift-kube-descheduler-operator** and click **Delete**.
5. Delete the **KubeDescheduler** CRD.
  - a. Navigate to **Administration** → **Custom Resource Definitions**
  - b. Enter **KubeDescheduler** into the filter box.
  - c. Click the Options menu  next to the **KubeDescheduler** entry and select **Delete CustomResourceDefinition**.
  - d. In the confirmation dialog, click **Delete**.

## 4.10. SECONDARY SCHEDULER

### 4.10.1. Secondary scheduler overview

You can install the Secondary Scheduler Operator to run a custom secondary scheduler alongside the default scheduler to schedule pods.

#### 4.10.1.1. About the Secondary Scheduler Operator

The Secondary Scheduler Operator for Red Hat OpenShift provides a way to deploy a custom secondary scheduler in OpenShift Container Platform. The secondary scheduler runs alongside the default scheduler to schedule pods. Pod configurations can specify which scheduler to use.

The custom scheduler must have the `/bin/kube-scheduler` binary and be based on the [Kubernetes scheduling framework](#).



### IMPORTANT

You can use the Secondary Scheduler Operator to deploy a custom secondary scheduler in OpenShift Container Platform, but Red Hat does not directly support the functionality of the custom secondary scheduler.

The Secondary Scheduler Operator creates the default roles and role bindings required by the secondary scheduler. You can specify which scheduling plugins to enable or disable by configuring the **KubeSchedulerConfiguration** resource for the secondary scheduler.

## 4.10.2. Secondary Scheduler Operator for Red Hat OpenShift release notes

The Secondary Scheduler Operator for Red Hat OpenShift allows you to deploy a custom secondary scheduler in your OpenShift Container Platform cluster.

These release notes track the development of the Secondary Scheduler Operator for Red Hat OpenShift.

For more information, see [About the Secondary Scheduler Operator](#).

### 4.10.2.1. Release notes for Secondary Scheduler Operator for Red Hat OpenShift 1.3.0

Issued: 2024-07-01

The following advisory is available for the Secondary Scheduler Operator for Red Hat OpenShift 1.3.0:

- [RHSA-2024:3637](#)

#### 4.10.2.1.1. New features and enhancements

- You can now install and use the Secondary Scheduler Operator in an OpenShift Container Platform cluster running in FIPS mode.



### IMPORTANT

To enable FIPS mode for your cluster, you must run the installation program from a Red Hat Enterprise Linux (RHEL) computer configured to operate in FIPS mode. For more information about configuring FIPS mode on RHEL, see [Switching RHEL to FIPS mode](#).

When running Red Hat Enterprise Linux (RHEL) or Red Hat Enterprise Linux CoreOS (RHCOS) booted in FIPS mode, OpenShift Container Platform core components use the RHEL cryptographic libraries that have been submitted to NIST for FIPS 140-2/140-3 Validation on only the x86\_64, ppc64le, and s390x architectures.

#### 4.10.2.1.2. Bug fixes

- This release of the Secondary Scheduler Operator addresses several Common Vulnerabilities and Exposures (CVEs).



#### 4.10.2.1.3. Known issues

- Currently, you cannot deploy additional resources, such as config maps, CRDs, or RBAC policies through the Secondary Scheduler Operator. Any resources other than roles and role bindings that are required by your custom secondary scheduler must be applied externally. ([WRKLDS-645](#))

### 4.10.3. Scheduling pods using a secondary scheduler

You can run a custom secondary scheduler in OpenShift Container Platform by installing the Secondary Scheduler Operator, deploying the secondary scheduler, and setting the secondary scheduler in the pod definition.

#### 4.10.3.1. Installing the Secondary Scheduler Operator

You can use the web console to install the Secondary Scheduler Operator for Red Hat OpenShift.

##### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- You have access to the OpenShift Container Platform web console.

##### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Create the required namespace for the Secondary Scheduler Operator for Red Hat OpenShift.
  - a. Navigate to **Administration** → **Namespaces** and click **Create Namespace**.
  - b. Enter **openshift-secondary-scheduler-operator** in the **Name** field and click **Create**.
3. Install the Secondary Scheduler Operator for Red Hat OpenShift.
  - a. Navigate to **Operators** → **OperatorHub**.
  - b. Enter **Secondary Scheduler Operator for Red Hat OpenShift** into the filter box.
  - c. Select the **Secondary Scheduler Operator for Red Hat OpenShift** and click **Install**.
  - d. On the **Install Operator** page:
    - i. The **Update channel** is set to **stable**, which installs the latest stable release of the Secondary Scheduler Operator for Red Hat OpenShift.
    - ii. Select **A specific namespace on the cluster** and select **openshift-secondary-scheduler-operator** from the drop-down menu.
    - iii. Select an **Update approval** strategy.
      - The **Automatic** strategy allows Operator Lifecycle Manager (OLM) to automatically update the Operator when a new version is available.
      - The **Manual** strategy requires a user with appropriate credentials to approve the Operator update.

iv. Click **Install**.

### Verification

1. Navigate to **Operators** → **Installed Operators**.
2. Verify that **Secondary Scheduler Operator for Red Hat OpenShift** is listed with a **Status** of **Succeeded**.

### 4.10.3.2. Deploying a secondary scheduler

After you have installed the Secondary Scheduler Operator, you can deploy a secondary scheduler.

### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- You have access to the OpenShift Container Platform web console.
- The Secondary Scheduler Operator for Red Hat OpenShift is installed.

### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Create config map to hold the configuration for the secondary scheduler.
  - a. Navigate to **Workloads** → **ConfigMaps**.
  - b. Click **Create ConfigMap**.
  - c. In the YAML editor, enter the config map definition that contains the necessary **KubeSchedulerConfiguration** configuration. For example:

```

apiVersion: v1
kind: ConfigMap
metadata:
  name: "secondary-scheduler-config"
  namespace: "openshift-secondary-scheduler-operator"
data:
  "config.yaml": |
    apiVersion: kubescheduler.config.k8s.io/v1beta3
    kind: KubeSchedulerConfiguration
    leaderElection:
      leaderElect: false
    profiles:
      - schedulerName: secondary-scheduler
      plugins:
        score:
          disabled:
            - name: NodeResourcesBalancedAllocation
            - name: NodeResourcesLeastAllocated
  
```

- 1 The name of the config map. This is used in the **Scheduler Config** field when creating the **SecondaryScheduler** CR.

- 2 The config map must be created in the **openshift-secondary-scheduler-operator** namespace.
- 3 The **KubeSchedulerConfiguration** resource for the secondary scheduler. For more information, see [KubeSchedulerConfiguration](#) in the Kubernetes API documentation.
- 4 The name of the secondary scheduler. Pods that set their **spec.schedulerName** field to this value are scheduled with this secondary scheduler.
- 5 The plugins to enable or disable for the secondary scheduler. For a list default scheduling plugins, see [Scheduling plugins](#) in the Kubernetes documentation.

d. Click **Create**.

3. Create the **SecondaryScheduler** CR:

- a. Navigate to **Operators → Installed Operators**.
- b. Select **Secondary Scheduler Operator for Red Hat OpenShift**
- c. Select the **Secondary Scheduler** tab and click **Create SecondaryScheduler**.
- d. The **Name** field defaults to **cluster**; do not change this name.
- e. The **Scheduler Config** field defaults to **secondary-scheduler-config**. Ensure that this value matches the name of the config map created earlier in this procedure.
- f. In the **Scheduler Image** field, enter the image name for your custom scheduler.



#### IMPORTANT

Red Hat does not directly support the functionality of your custom secondary scheduler.

g. Click **Create**.

#### 4.10.3.3. Scheduling a pod using the secondary scheduler

To schedule a pod using the secondary scheduler, set the **schedulerName** field in the pod definition.

##### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- You have access to the OpenShift Container Platform web console.
- The Secondary Scheduler Operator for Red Hat OpenShift is installed.
- A secondary scheduler is configured.

##### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Navigate to **Workloads → Pods**.

- Click **Create Pod**.
- In the YAML editor, enter the desired pod configuration and add the **schedulerName** field:

```

apiVersion: v1
kind: Pod
metadata:
  name: nginx
  namespace: default
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: nginx
    image: nginx:1.14.2
    ports:
    - containerPort: 80
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
  schedulerName: secondary-scheduler 1

```

- The **schedulerName** field must match the name that is defined in the config map when you configured the secondary scheduler.

- Click **Create**.

## Verification

- Log in to the OpenShift CLI.
- Describe the pod using the following command:

```
$ oc describe pod nginx -n default
```

### Example output

```

Name:      nginx
Namespace: default
Priority:   0
Node:      ci-ln-t0w4r1k-72292-xkqs4-worker-b-xqkxp/10.0.128.3
...
Events:
  Type     Reason          Age    From          Message
  ----     -
  Normal   Scheduled       12s   secondary-scheduler Successfully assigned default/nginx to
ci-ln-t0w4r1k-72292-xkqs4-worker-b-xqkxp
...

```

- In the events table, find the event with a message similar to **Successfully assigned <namespace>/<pod\_name> to <node\_name>**.

4. In the "From" column, verify that the event was generated from the secondary scheduler and not the default scheduler.



#### NOTE

You can also check the **secondary-scheduler-\*** pod logs in the **openshift-secondary-scheduler-namespace** to verify that the pod was scheduled by the secondary scheduler.

### 4.10.4. Uninstalling the Secondary Scheduler Operator

You can remove the Secondary Scheduler Operator for Red Hat OpenShift from OpenShift Container Platform by uninstalling the Operator and removing its related resources.


#### 4.10.4.1. Uninstalling the Secondary Scheduler Operator

You can uninstall the Secondary Scheduler Operator for Red Hat OpenShift by using the web console.

##### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- You have access to the OpenShift Container Platform web console.
- The Secondary Scheduler Operator for Red Hat OpenShift is installed.

##### Procedure

1. Log in to the OpenShift Container Platform web console.
2. Uninstall the Secondary Scheduler Operator for Red Hat OpenShift Operator.
  - a. Navigate to **Operators** → **Installed Operators**.
  - b. Click the Options menu  next to the **Secondary Scheduler Operator** entry and click **Uninstall Operator**.
  - c. In the confirmation dialog, click **Uninstall**.

#### 4.10.4.2. Removing Secondary Scheduler Operator resources



Optionally, after uninstalling the Secondary Scheduler Operator for Red Hat OpenShift, you can remove its related resources from your cluster.

##### Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.
- You have access to the OpenShift Container Platform web console.

##### Procedure

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

2. Remove CRDs that were installed by the Secondary Scheduler Operator:
  - a. Navigate to **Administration** → **CustomResourceDefinitions**.
  - b. Enter **SecondaryScheduler** in the **Name** field to filter the CRDs.
  - c. Click the Options menu  next to the **SecondaryScheduler** CRD and select **Delete Custom Resource Definition**:
3. Remove the **openshift-secondary-scheduler-operator** namespace.
  - a. Navigate to **Administration** → **Namespaces**.
  - b. Click the Options menu  next to the **openshift-secondary-scheduler-operator** and select **Delete Namespace**.
  - c. In the confirmation dialog, enter **openshift-secondary-scheduler-operator** in the field and click **Delete**.

## CHAPTER 5. USING JOBS AND DAEMONSETS

### 5.1. RUNNING BACKGROUND TASKS ON NODES AUTOMATICALLY WITH DAEMON SETS

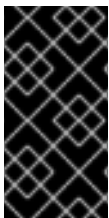
As an administrator, you can create and use daemon sets to run replicas of a pod on specific or all nodes in an OpenShift Container Platform cluster.

A daemon set ensures that all (or some) nodes run a copy of a pod. As nodes are added to the cluster, pods are added to the cluster. As nodes are removed from the cluster, those pods are removed through garbage collection. Deleting a daemon set will clean up the pods it created.

You can use daemon sets to create shared storage, run a logging pod on every node in your cluster, or deploy a monitoring agent on every node.

For security reasons, the cluster administrators and the project administrators can create daemon sets.

For more information on daemon sets, see the [Kubernetes documentation](#).



#### IMPORTANT

Daemon set scheduling is incompatible with project's default node selector. If you fail to disable it, the daemon set gets restricted by merging with the default node selector. This results in frequent pod recreates on the nodes that got unselected by the merged node selector, which in turn puts unwanted load on the cluster.

#### 5.1.1. Scheduled by default scheduler

A daemon set ensures that all eligible nodes run a copy of a pod. Normally, the node that a pod runs on is selected by the Kubernetes scheduler. However, daemon set pods are created and scheduled by the daemon set controller. That introduces the following issues:

- Inconsistent pod behavior: Normal pods waiting to be scheduled are created and in Pending state, but daemon set pods are not created in **Pending** state. This is confusing to the user.
- Pod preemption is handled by default scheduler. When preemption is enabled, the daemon set controller will make scheduling decisions without considering pod priority and preemption.

The **ScheduleDaemonSetPods** feature, enabled by default in OpenShift Container Platform, lets you schedule daemon sets using the default scheduler instead of the daemon set controller, by adding the **NodeAffinity** term to the daemon set pods, instead of the **spec.nodeName** term. The default scheduler is then used to bind the pod to the target host. If node affinity of the daemon set pod already exists, it is replaced. The daemon set controller only performs these operations when creating or modifying daemon set pods, and no changes are made to the **spec.template** of the daemon set.

```
kind: Pod
apiVersion: v1
metadata:
  name: hello-node-6fbccf8d9-9tmzr
#...
spec:
  nodeAffinity:
    requiredDuringSchedulingIgnoredDuringExecution:
      nodeSelectorTerms:
```

```

- matchFields:
- key: metadata.name
  operator: In
  values:
- target-host-name
#...
```

In addition, a **node.kubernetes.io/unschedulable:NoSchedule** toleration is added automatically to daemon set pods. The default scheduler ignores unschedulable Nodes when scheduling daemon set pods.

## 5.1.2. Creating daemonsets

When creating daemon sets, the **nodeSelector** field is used to indicate the nodes on which the daemon set should deploy replicas.

### Prerequisites

- Before you start using daemon sets, disable the default project-wide node selector in your namespace, by setting the namespace annotation **openshift.io/node-selector** to an empty string:

```
$ oc patch namespace myproject -p \
  '{"metadata": {"annotations": {"openshift.io/node-selector": ""}}}'
```

### TIP

You can alternatively apply the following YAML to disable the default project-wide node selector for a namespace:

```

apiVersion: v1
kind: Namespace
metadata:
  name: <namespace>
  annotations:
    openshift.io/node-selector: ""
#...
```

- If you are creating a new project, overwrite the default node selector:

```
$ oc adm new-project <name> --node-selector=""
```

### Procedure

To create a daemon set:

1. Define the daemon set yaml file:

```

apiVersion: apps/v1
kind: DaemonSet
metadata:
  name: hello-daemonset
spec:
```



```

selector:
  matchLabels:
    name: hello-daemonset 1
template:
  metadata:
    labels:
      name: hello-daemonset 2
  spec:
    nodeSelector: 3
      role: worker
    containers:
      - image: openshift/hello-openshift
        imagePullPolicy: Always
        name: registry
        ports:
          - containerPort: 80
            protocol: TCP
        resources: {}
        terminationMessagePath: /dev/termination-log
    serviceAccount: default
    terminationGracePeriodSeconds: 10
#...

```

- 1** The label selector that determines which pods belong to the daemon set.
- 2** The pod template's label selector. Must match the label selector above.
- 3** The node selector that determines on which nodes pod replicas should be deployed. A matching label must be present on the node.

2. Create the daemon set object:

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

3. To verify that the pods were created, and that each node has a pod replica:

a. Find the daemonset pods:

```
$ oc get pods
```

#### Example output

```

hello-daemonset-cx6md 1/1    Running 0    2m
hello-daemonset-e3md9 1/1    Running 0    2m

```

b. View the pods to verify the pod has been placed onto the node:

```
$ oc describe pod/hello-daemonset-cx6md|grep Node
```

#### Example output

```
Node:    openshift-node01.hostname.com/10.14.20.134
```

```
-
```

```
$ oc describe pod/hello-daemonset-e3md9|grep Node
```

### Example output

```
Node:      openshift-node02.hostname.com/10.14.20.137
```

### IMPORTANT

- If you update a daemon set pod template, the existing pod replicas are not affected.
- If you delete a daemon set and then create a new daemon set with a different template but the same label selector, it recognizes any existing pod replicas as having matching labels and thus does not update them or create new replicas despite a mismatch in the pod template.
- If you change node labels, the daemon set adds pods to nodes that match the new labels and deletes pods from nodes that do not match the new labels.

To update a daemon set, force new pod replicas to be created by deleting the old replicas or nodes.

## 5.2. RUNNING TASKS IN PODS USING JOBS

A *job* executes a task in your OpenShift Container Platform cluster.

A job tracks the overall progress of a task and updates its status with information about active, succeeded, and failed pods. Deleting a job will clean up any pod replicas it created. Jobs are part of the Kubernetes API, which can be managed with **oc** commands like other object types.

### Sample Job specification

```
apiVersion: batch/v1
kind: Job
metadata:
  name: pi
spec:
  parallelism: 1 1
  completions: 1 2
  activeDeadlineSeconds: 1800 3
  backoffLimit: 6 4
  template: 5
    metadata:
      name: pi
    spec:
      containers:
      - name: pi
        image: perl
        command: ["perl", "-Mbignum=bpi", "-wle", "print bpi(2000)"]
      restartPolicy: OnFailure 6
#...
```

- 1** The pod replicas a job should run in parallel.

- 2 Successful pod completions are needed to mark a job completed.
- 3 The maximum duration the job can run.
- 4 The number of retries for a job.
- 5 The template for the pod the controller creates.
- 6 The restart policy of the pod.

### Additional resources

- [Jobs](#) in the Kubernetes documentation

## 5.2.1. Understanding jobs and cron jobs

A job tracks the overall progress of a task and updates its status with information about active, succeeded, and failed pods. Deleting a job cleans up any pods it created. Jobs are part of the Kubernetes API, which can be managed with **oc** commands like other object types.

There are two possible resource types that allow creating run-once objects in OpenShift Container Platform:

### Job

A regular job is a run-once object that creates a task and ensures the job finishes.

There are three main types of task suitable to run as a job:

- Non-parallel jobs:
  - A job that starts only one pod, unless the pod fails.
  - The job is complete as soon as its pod terminates successfully.
- Parallel jobs with a fixed completion count:
  - a job that starts multiple pods.
  - The job represents the overall task and is complete when there is one successful pod for each value in the range **1** to the **completions** value.
- Parallel jobs with a work queue:
  - A job with multiple parallel worker processes in a given pod.
  - OpenShift Container Platform coordinates pods to determine what each should work on or use an external queue service.
  - Each pod is independently capable of determining whether or not all peer pods are complete and that the entire job is done.
  - When any pod from the job terminates with success, no new pods are created.
  - When at least one pod has terminated with success and all pods are terminated, the job is successfully completed.

- When any pod has exited with success, no other pod should be doing any work for this task or writing any output. Pods should all be in the process of exiting. For more information about how to make use of the different types of job, see [Job Patterns](#) in the Kubernetes documentation.

## Cron job

A job can be scheduled to run multiple times, using a cron job.

A *cron job* builds on a regular job by allowing you to specify how the job should be run. Cron jobs are part of the [Kubernetes](#) API, which can be managed with **oc** commands like other object types.

Cron jobs are useful for creating periodic and recurring tasks, like running backups or sending emails. Cron jobs can also schedule individual tasks for a specific time, such as if you want to schedule a job for a low activity period. A cron job creates a **Job** object based on the timezone configured on the control plane node that runs the cronjob controller.



### WARNING

A cron job creates a **Job** object approximately once per execution time of its schedule, but there are circumstances in which it fails to create a job or two jobs might be created. Therefore, jobs must be idempotent and you must configure history limits.

### 5.2.1.1. Understanding how to create jobs

Both resource types require a job configuration that consists of the following key parts:

- A pod template, which describes the pod that OpenShift Container Platform creates.
- The **parallelism** parameter, which specifies how many pods running in parallel at any point in time should execute a job.
  - For non-parallel jobs, leave unset. When unset, defaults to **1**.
- The **completions** parameter, specifying how many successful pod completions are needed to finish a job.
  - For non-parallel jobs, leave unset. When unset, defaults to **1**.
  - For parallel jobs with a fixed completion count, specify a value.
  - For parallel jobs with a work queue, leave unset. When unset defaults to the **parallelism** value.

### 5.2.1.2. Understanding how to set a maximum duration for jobs

When defining a job, you can define its maximum duration by setting the **activeDeadlineSeconds** field. It is specified in seconds and is not set by default. When not set, there is no maximum duration enforced.

The maximum duration is counted from the time when a first pod gets scheduled in the system, and defines how long a job can be active. It tracks overall time of an execution. After reaching the specified timeout, the job is terminated by OpenShift Container Platform.

### 5.2.1.3. Understanding how to set a job back off policy for pod failure

A job can be considered failed, after a set amount of retries due to a logical error in configuration or other similar reasons. Failed pods associated with the job are recreated by the controller with an exponential back off delay (**10s, 20s, 40s** ...) capped at six minutes. The limit is reset if no new failed pods appear between controller checks.

Use the **spec.backoffLimit** parameter to set the number of retries for a job.

### 5.2.1.4. Understanding how to configure a cron job to remove artifacts

Cron jobs can leave behind artifact resources such as jobs or pods. As a user it is important to configure history limits so that old jobs and their pods are properly cleaned. There are two fields within cron job's spec responsible for that:

- **.spec.successfulJobsHistoryLimit**. The number of successful finished jobs to retain (defaults to 3).
- **.spec.failedJobsHistoryLimit**. The number of failed finished jobs to retain (defaults to 1).

#### TIP

- Delete cron jobs that you no longer need:

```
$ oc delete cronjob/<cron_job_name>
```

Doing this prevents them from generating unnecessary artifacts.

- You can suspend further executions by setting the **spec.suspend** to true. All subsequent executions are suspended until you reset to **false**.

### 5.2.1.5. Known limitations

The job specification restart policy only applies to the *pods*, and not the *job controller*. However, the job controller is hard-coded to keep retrying jobs to completion.

As such, **restartPolicy: Never** or **--restart=Never** results in the same behavior as **restartPolicy: OnFailure** or **--restart=OnFailure**. That is, when a job fails it is restarted automatically until it succeeds (or is manually discarded). The policy only sets which subsystem performs the restart.

With the **Never** policy, the *job controller* performs the restart. With each attempt, the job controller increments the number of failures in the job status and create new pods. This means that with each failed attempt, the number of pods increases.

With the **OnFailure** policy, *kubelet* performs the restart. Each attempt does not increment the number of failures in the job status. In addition, kubelet will retry failed jobs starting pods on the same nodes.

## 5.2.2. Creating jobs

You create a job in OpenShift Container Platform by creating a job object.

## Procedure

To create a job:

1. Create a YAML file similar to the following:

```

apiVersion: batch/v1
kind: Job
metadata:
  name: pi
spec:
  parallelism: 1 1
  completions: 1 2
  activeDeadlineSeconds: 1800 3
  backoffLimit: 6 4
  template: 5
    metadata:
      name: pi
    spec:
      containers:
      - name: pi
        image: perl
        command: ["perl", "-Mbignum=bpi", "-wle", "print bpi(2000)"]
      restartPolicy: OnFailure 6
#...
```

- 1** Optional: Specify how many pod replicas a job should run in parallel; defaults to **1**.
  - For non-parallel jobs, leave unset. When unset, defaults to **1**.
- 2** Optional: Specify how many successful pod completions are needed to mark a job completed.
  - For non-parallel jobs, leave unset. When unset, defaults to **1**.
  - For parallel jobs with a fixed completion count, specify the number of completions.
  - For parallel jobs with a work queue, leave unset. When unset defaults to the **parallelism** value.
- 3** Optional: Specify the maximum duration the job can run.
- 4** Optional: Specify the number of retries for a job. This field defaults to six.
- 5** Specify the template for the pod the controller creates.
- 6** Specify the restart policy of the pod:
  - **Never**. Do not restart the job.
  - **OnFailure**. Restart the job only if it fails.
  - **Always**. Always restart the job.  
For details on how OpenShift Container Platform uses restart policy with failed containers, see the [Example States](#) in the Kubernetes documentation.

2. Create the job:

```
$ oc create -f <file-name>.yaml
```



## NOTE

You can also create and launch a job from a single command using **oc create job**. The following command creates and launches a job similar to the one specified in the previous example:

```
$ oc create job pi --image=perl -- perl -Mbignum=bpi -wle 'print bpi(2000)'
```

### 5.2.3. Creating cron jobs

You create a cron job in OpenShift Container Platform by creating a job object.

#### Procedure

To create a cron job:

1. Create a YAML file similar to the following:

```
apiVersion: batch/v1
kind: CronJob
metadata:
  name: pi
spec:
  schedule: "*/1 * * * *" 1
  timeZone: Etc/UTC 2
  concurrencyPolicy: "Replace" 3
  startingDeadlineSeconds: 200 4
  suspend: true 5
  successfulJobsHistoryLimit: 3 6
  failedJobsHistoryLimit: 1 7
  jobTemplate: 8
    spec:
      template:
        metadata:
          labels: 9
            parent: "cronjobpi"
        spec:
          containers:
            - name: pi
              image: perl
              command: ["perl", "-Mbignum=bpi", "-wle", "print bpi(2000)"]
              restartPolicy: OnFailure 10
#...
```

- 1 Schedule for the job specified in [cron format](#). In this example, the job will run every minute.
- 2 An optional time zone for the schedule. See [List of tz database time zones](#) for valid options. If not specified, the Kubernetes controller manager interprets the schedule relative to its local time zone.

- 3 An optional concurrency policy, specifying how to treat concurrent jobs within a cron job. Only one of the following concurrent policies may be specified. If not specified, this
  - **Allow** allows cron jobs to run concurrently.
  - **Forbid** forbids concurrent runs, skipping the next run if the previous has not finished yet.
  - **Replace** cancels the currently running job and replaces it with a new one.
- 4 An optional deadline (in seconds) for starting the job if it misses its scheduled time for any reason. Missed jobs executions will be counted as failed ones. If not specified, there is no deadline.
- 5 An optional flag allowing the suspension of a cron job. If set to **true**, all subsequent executions will be suspended.
- 6 The number of successful finished jobs to retain (defaults to 3).
- 7 The number of failed finished jobs to retain (defaults to 1).
- 8 Job template. This is similar to the job example.
- 9 Sets a label for jobs spawned by this cron job.
- 10 The restart policy of the pod. This does not apply to the job controller.

2. Create the cron job:

```
$ oc create -f <file-name>.yaml
```



#### NOTE

You can also create and launch a cron job from a single command using **oc create cronjob**. The following command creates and launches a cron job similar to the one specified in the previous example:

```
$ oc create cronjob pi --image=perl --schedule='*/1 * * * *' -- perl -Mbignum=bpi -wle 'print bpi(2000)'
```

With **oc create cronjob**, the **--schedule** option accepts schedules in [cron format](#).



## CHAPTER 6. WORKING WITH NODES

### 6.1. VIEWING AND LISTING THE NODES IN YOUR OPENSIFT CONTAINER PLATFORM CLUSTER

You can list all the nodes in your cluster to obtain information such as status, age, memory usage, and details about the nodes.

When you perform node management operations, the CLI interacts with node objects that are representations of actual node hosts. The master uses the information from node objects to validate nodes with health checks.

#### 6.1.1. About listing all the nodes in a cluster

You can get detailed information on the nodes in the cluster.

- The following command lists all nodes:

```
$ oc get nodes
```

The following example is a cluster with healthy nodes:

```
$ oc get nodes
```

#### Example output

```
NAME                STATUS  ROLES  AGE  VERSION
master.example.com  Ready  master  7h  v1.30.3
node1.example.com   Ready  worker  7h  v1.30.3
node2.example.com   Ready  worker  7h  v1.30.3
```

The following example is a cluster with one unhealthy node:

```
$ oc get nodes
```

#### Example output

```
NAME                STATUS                ROLES  AGE  VERSION
master.example.com  Ready                master  7h  v1.30.3
node1.example.com   NotReady,SchedulingDisabled  worker  7h  v1.30.3
node2.example.com   Ready                worker  7h  v1.30.3
```

The conditions that trigger a **NotReady** status are shown later in this section.

- The **-o wide** option provides additional information on nodes.

```
$ oc get nodes -o wide
```

#### Example output

```
NAME                STATUS  ROLES  AGE  VERSION  INTERNAL-IP  EXTERNAL-IP
```

OS-IMAGE RUNTIME				KERNEL-VERSION		CONTAINER-
master.example.com	Ready	master	171m	v1.30.3	10.0.129.108	<none> Red Hat
Enterprise Linux CoreOS				48.83.202103210901-0 (Ootpa)	4.18.0-240.15.1.el8_3.x86_64	
cri-o://1.30.3-30.rhaos4.10.gitf2f339d.el8-dev						
node1.example.com	Ready	worker	72m	v1.30.3	10.0.129.222	<none> Red Hat
Enterprise Linux CoreOS				48.83.202103210901-0 (Ootpa)	4.18.0-240.15.1.el8_3.x86_64	
cri-o://1.30.3-30.rhaos4.10.gitf2f339d.el8-dev						
node2.example.com	Ready	worker	164m	v1.30.3	10.0.142.150	<none> Red Hat
Enterprise Linux CoreOS				48.83.202103210901-0 (Ootpa)	4.18.0-240.15.1.el8_3.x86_64	
cri-o://1.30.3-30.rhaos4.10.gitf2f339d.el8-dev						

- The following command lists information about a single node:

```
$ oc get node <node>
```

For example:

```
$ oc get node node1.example.com
```

### Example output

NAME	STATUS	ROLES	AGE	VERSION
node1.example.com	Ready	worker	7h	v1.30.3

- The following command provides more detailed information about a specific node, including the reason for the current condition:

```
$ oc describe node <node>
```

For example:

```
$ oc describe node node1.example.com
```



### NOTE

The following example contains some values that are specific to OpenShift Container Platform on AWS.

### Example output

```
Name:          node1.example.com 1
Roles:        worker 2
Labels:       kubernetes.io/os=linux
              kubernetes.io/hostname=ip-10-0-131-14
              kubernetes.io/arch=amd64 3
              node-role.kubernetes.io/worker=
              node.kubernetes.io/instance-type=m4.large
              node.openshift.io/os_id=rhcos
              node.openshift.io/os_version=4.5
              region=east
              topology.kubernetes.io/region=us-east-1
```

```

    topology.kubernetes.io/zone=us-east-1a
Annotations:   cluster.k8s.io/machine: openshift-machine-api/ahardin-worker-us-east-2a-q5dzc
4
    machineconfiguration.openshift.io/currentConfig: worker-
309c228e8b3a92e2235edd544c62fea8
    machineconfiguration.openshift.io/desiredConfig: worker-
309c228e8b3a92e2235edd544c62fea8
    machineconfiguration.openshift.io/state: Done
    volumes.kubernetes.io/controller-managed-attach-detach: true
CreationTimestamp: Wed, 13 Feb 2019 11:05:57 -0500
Taints:       <none> 5
Unschedulable: false
Conditions:   6
  Type        Status LastHeartbeatTime           LastTransitionTime          Reason
  Message
  ----
  OutOfDisk   False  Wed, 13 Feb 2019 15:09:42 -0500  Wed, 13 Feb 2019 11:05:57 -0500
  KubeletHasSufficientDisk kubelet has sufficient disk space available
  MemoryPressure False  Wed, 13 Feb 2019 15:09:42 -0500  Wed, 13 Feb 2019 11:05:57 -0500
  KubeletHasSufficientMemory kubelet has sufficient memory available
  DiskPressure False  Wed, 13 Feb 2019 15:09:42 -0500  Wed, 13 Feb 2019 11:05:57 -0500
  KubeletHasNoDiskPressure kubelet has no disk pressure
  PIDPressure False  Wed, 13 Feb 2019 15:09:42 -0500  Wed, 13 Feb 2019 11:05:57 -0500
  KubeletHasSufficientPID kubelet has sufficient PID available
  Ready       True   Wed, 13 Feb 2019 15:09:42 -0500  Wed, 13 Feb 2019 11:07:09 -0500
  KubeletReady kubelet is posting ready status
Addresses:    7
  InternalIP: 10.0.140.16
  InternalDNS: ip-10-0-140-16.us-east-2.compute.internal
  Hostname:   ip-10-0-140-16.us-east-2.compute.internal
Capacity:    8
  attachable-volumes-aws-ebs: 39
  cpu:                          2
  hugepages-1Gi:                0
  hugepages-2Mi:                0
  memory:                        8172516Ki
  pods:                          250
Allocatable:
  attachable-volumes-aws-ebs: 39
  cpu:                          1500m
  hugepages-1Gi:                0
  hugepages-2Mi:                0
  memory:                        7558116Ki
  pods:                          250
System Info:  9
  Machine ID:          63787c9534c24fde9a0cde35c13f1f66
  System UUID:        EC22BF97-A006-4A58-6AF8-0A38DEEA122A
  Boot ID:            f24ad37d-2594-46b4-8830-7f7555918325
  Kernel Version:    3.10.0-957.5.1.el7.x86_64
  OS Image:          Red Hat Enterprise Linux CoreOS 410.8.20190520.0 (Ootpa)
  Operating System:  linux
  Architecture:      amd64
  Container Runtime Version: cri-o://1.30.3-0.6.dev.rhaos4.3.git9ad059b.el8-rc2
  Kubelet Version:    v1.30.3
  Kube-Proxy Version: v1.30.3

```

```

PodCIDR:                10.128.4.0/24
ProviderID:             aws:///us-east-2a/i-04e87b31dc6b3e171
Non-terminated Pods:   (12 in total) 10
  Namespace              Name                      CPU Requests  CPU Limits  Memory
  Requests  Memory Limits
-----
  openshift-cluster-node-tuning-operator tuned-hdl5q          0 (0%)      0 (0%)      0 (0%)
0 (0%)
  openshift-dns          dns-default-l69zr    0 (0%)      0 (0%)      0 (0%)      0
(0%)
  openshift-image-registry node-ca-9hmcg        0 (0%)      0 (0%)      0 (0%)
0 (0%)
  openshift-ingress      router-default-76455c45c-c5ptv  0 (0%)      0 (0%)      0 (0%)
0 (0%)
  openshift-machine-config-operator machine-config-daemon-cvqw9      20m (1%)    0 (0%)
50Mi (0%)  0 (0%)
  openshift-marketplace  community-operators-f67fh        0 (0%)      0 (0%)      0 (0%)
0 (0%)
  openshift-monitoring   alertmanager-main-0             50m (3%)    50m (3%)    210Mi
(2%)  10Mi (0%)
  openshift-monitoring   node-exporter-l7q8d             10m (0%)    20m (1%)    20Mi
(0%)  40Mi (0%)
  openshift-monitoring   prometheus-adapter-75d769c874-hvb85  0 (0%)      0 (0%)      0
(0%)  0 (0%)
  openshift-multus       multus-kw8w5                    0 (0%)      0 (0%)      0 (0%)      0
(0%)
  openshift-ovn-kubernetes ovnkube-node-t4dsn              80m (0%)    0 (0%)
1630Mi (0%)  0 (0%)

```

Allocated resources:

(Total limits may be over 100 percent, i.e., overcommitted.)

```

Resource      Requests  Limits
-----
cpu           380m (25%) 270m (18%)
memory        880Mi (11%) 250Mi (3%)
attachable-volumes-aws-efs 0      0

```

Events: **11**

```

Type Reason      Age      From      Message
----
Normal NodeHasSufficientPID 6d (x5 over 6d) kubelet, m01.example.com Node
m01.example.com status is now: NodeHasSufficientPID
Normal NodeAllocatableEnforced 6d kubelet, m01.example.com Updated Node
Allocatable limit across pods
Normal NodeHasSufficientMemory 6d (x6 over 6d) kubelet, m01.example.com Node
m01.example.com status is now: NodeHasSufficientMemory
Normal NodeHasNoDiskPressure 6d (x6 over 6d) kubelet, m01.example.com Node
m01.example.com status is now: NodeHasNoDiskPressure
Normal NodeHasSufficientDisk 6d (x6 over 6d) kubelet, m01.example.com Node
m01.example.com status is now: NodeHasSufficientDisk
Normal NodeHasSufficientPID 6d kubelet, m01.example.com Node
m01.example.com status is now: NodeHasSufficientPID
Normal Starting 6d kubelet, m01.example.com Starting kubelet.
#...

```

**1** The name of the node.

- 2 The role of the node, either **master** or **worker**.
- 3 The labels applied to the node.
- 4 The annotations applied to the node.
- 5 The taints applied to the node.
- 6 The node conditions and status. The **conditions** stanza lists the **Ready**, **PIDPressure**, **MemoryPressure**, **DiskPressure** and **OutOfDisk** status. These condition are described later in this section.
- 7 The IP address and hostname of the node.
- 8 The pod resources and allocatable resources.
- 9 Information about the node host.
- 10 The pods on the node.
- 11 The events reported by the node.



#### NOTE

The control plane label is not automatically added to newly created or updated master nodes. If you want to use the control plane label for your nodes, you can manually configure the label. For more information, see *Understanding how to update labels on nodes* in the *Additional resources* section.

Among the information shown for nodes, the following node conditions appear in the output of the commands shown in this section:

Table 6.1. Node Conditions

Condition	Description
<b>Ready</b>	If <b>true</b> , the node is healthy and ready to accept pods. If <b>false</b> , the node is not healthy and is not accepting pods. If <b>unknown</b> , the node controller has not received a heartbeat from the node for the <b>node-monitor-grace-period</b> (the default is 40 seconds).
<b>DiskPressure</b>	If <b>true</b> , the disk capacity is low.
<b>MemoryPressure</b>	If <b>true</b> , the node memory is low.
<b>PIDPressure</b>	If <b>true</b> , there are too many processes on the node.
<b>OutOfDisk</b>	If <b>true</b> , the node has insufficient free space on the node for adding new pods.
<b>NetworkUnavailable</b>	If <b>true</b> , the network for the node is not correctly configured.

Condition	Description
<b>NotReady</b>	If <b>true</b> , one of the underlying components, such as the container runtime or network, is experiencing issues or is not yet configured.
<b>SchedulingDisabled</b>	Pods cannot be scheduled for placement on the node.

### Additional resources

- [Understanding how to update labels on nodes](#)

## 6.1.2. Listing pods on a node in your cluster

You can list all the pods on a specific node.

### Procedure

- To list all or selected pods on one or more nodes:

```
$ oc describe node <node1> <node2>
```

For example:

```
$ oc describe node ip-10-0-128-218.ec2.internal
```

- To list all or selected pods on selected nodes:

```
$ oc describe node --selector=<node_selector>
```

```
$ oc describe node --selector=kubernetes.io/os
```

Or:

```
$ oc describe node -l=<pod_selector>
```

```
$ oc describe node -l node-role.kubernetes.io/worker
```

- To list all pods on a specific node, including terminated pods:

```
$ oc get pod --all-namespaces --field-selector=spec.nodeName=<nodename>
```

## 6.1.3. Viewing memory and CPU usage statistics on your nodes

You can display usage statistics about nodes, which provide the runtime environments for containers. These usage statistics include CPU, memory, and storage consumption.

### Prerequisites

- You must have **cluster-reader** permission to view the usage statistics.

- Metrics must be installed to view the usage statistics.

### Procedure

- To view the usage statistics:

```
$ oc adm top nodes
```

### Example output

```
NAME                                CPU(cores) CPU%  MEMORY(bytes) MEMORY%
ip-10-0-12-143.ec2.compute.internal 1503m      100% 4533Mi 61%
ip-10-0-132-16.ec2.compute.internal 76m        5%   1391Mi 18%
ip-10-0-140-137.ec2.compute.internal 398m       26%  2473Mi 33%
ip-10-0-142-44.ec2.compute.internal 656m       43%  6119Mi 82%
ip-10-0-146-165.ec2.compute.internal 188m       12%  3367Mi 45%
ip-10-0-19-62.ec2.compute.internal  896m       59%  5754Mi 77%
ip-10-0-44-193.ec2.compute.internal 632m       42%  5349Mi 72%
```

- To view the usage statistics for nodes with labels:

```
$ oc adm top node --selector="
```

You must choose the selector (label query) to filter on. Supports `=`, `==`, and `!=`.

## 6.2. WORKING WITH NODES

As an administrator, you can perform several tasks to make your clusters more efficient.

### 6.2.1. Understanding how to evacuate pods on nodes

Evacuating pods allows you to migrate all or selected pods from a given node or nodes.

You can only evacuate pods backed by a replication controller. The replication controller creates new pods on other nodes and removes the existing pods from the specified node(s).

Bare pods, meaning those not backed by a replication controller, are unaffected by default. You can evacuate a subset of pods by specifying a pod-selector. Pod selectors are based on labels, so all the pods with the specified label will be evacuated.

### Procedure

1. Mark the nodes unschedulable before performing the pod evacuation.
  - a. Mark the node as unschedulable:

```
$ oc adm cordon <node1>
```

### Example output

```
node/<node1> cordoned
```

- b. Check that the node status is **Ready,SchedulingDisabled**:

```
$ oc get node <node1>
```

### Example output

```
NAME          STATUS             ROLES    AGE    VERSION
<node1>      Ready,SchedulingDisabled  worker  1d    v1.30.3
```

2. Evacuate the pods using one of the following methods:

- Evacuate all or selected pods on one or more nodes:

```
$ oc adm drain <node1> <node2> [--pod-selector=<pod_selector>]
```

- Force the deletion of bare pods using the **--force** option. When set to **true**, deletion continues even if there are pods not managed by a replication controller, replica set, job, daemon set, or stateful set:

```
$ oc adm drain <node1> <node2> --force=true
```

- Set a period of time in seconds for each pod to terminate gracefully, use **--grace-period**. If negative, the default value specified in the pod will be used:

```
$ oc adm drain <node1> <node2> --grace-period=-1
```

- Ignore pods managed by daemon sets using the **--ignore-daemonsets** flag set to **true**:

```
$ oc adm drain <node1> <node2> --ignore-daemonsets=true
```

- Set the length of time to wait before giving up using the **--timeout** flag. A value of **0** sets an infinite length of time:

```
$ oc adm drain <node1> <node2> --timeout=5s
```

- Delete pods even if there are pods using **emptyDir** volumes by setting the **--delete-emptydir-data** flag to **true**. Local data is deleted when the node is drained:

```
$ oc adm drain <node1> <node2> --delete-emptydir-data=true
```

- List objects that will be migrated without actually performing the evacuation, using the **--dry-run** option set to **true**:

```
$ oc adm drain <node1> <node2> --dry-run=true
```

Instead of specifying specific node names (for example, **<node1> <node2>**), you can use the **--selector=<node\_selector>** option to evacuate pods on selected nodes.

3. Mark the node as schedulable when done.

```
$ oc adm uncordon <node1>
```

## 6.2.2. Understanding how to update labels on nodes



You can update any label on a node.

Node labels are not persisted after a node is deleted even if the node is backed up by a Machine.



## NOTE

Any change to a **MachineSet** object is not applied to existing machines owned by the compute machine set. For example, labels edited or added to an existing **MachineSet** object are not propagated to existing machines and nodes associated with the compute machine set.

- The following command adds or updates labels on a node:

```
$ oc label node <node> <key_1>=<value_1> ... <key_n>=<value_n>
```

For example:

```
$ oc label nodes webconsole-7f7f6 unhealthy=true
```

## TIP

You can alternatively apply the following YAML to apply the label:

```
kind: Node
apiVersion: v1
metadata:
  name: webconsole-7f7f6
  labels:
    unhealthy: 'true'
#...
```

- The following command updates all pods in the namespace:

```
$ oc label pods --all <key_1>=<value_1>
```

For example:

```
$ oc label pods --all status=unhealthy
```

### 6.2.3. Understanding how to mark nodes as unschedulable or schedulable

By default, healthy nodes with a **Ready** status are marked as schedulable, which means that you can place new pods on the node. Manually marking a node as unschedulable blocks any new pods from being scheduled on the node. Existing pods on the node are not affected.

- The following command marks a node or nodes as unschedulable:

#### Example output

```
$ oc adm cordon <node>
```

For example:

```
$ oc adm cordon node1.example.com
```

### Example output

```
node/node1.example.com cordoned
```

NAME	LABELS	STATUS
node1.example.com	kubernetes.io/hostname=node1.example.com	Ready,SchedulingDisabled

- The following command marks a currently unschedulable node or nodes as schedulable:

```
$ oc adm uncordon <node1>
```

Alternatively, instead of specifying specific node names (for example, **<node>**), you can use the **--selector=<node\_selector>** option to mark selected nodes as schedulable or unschedulable.

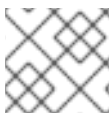
## 6.2.4. Handling errors in single-node OpenShift clusters when the node reboots without draining application pods

In single-node OpenShift clusters and in OpenShift Container Platform clusters in general, a situation can arise where a node reboot occurs without first draining the node. This can occur where an application pod requesting devices fails with the **UnexpectedAdmissionError** error. **Deployment**, **ReplicaSet**, or **DaemonSet** errors are reported because the application pods that require those devices start before the pod serving those devices. You cannot control the order of pod restarts.

While this behavior is to be expected, it can cause a pod to remain on the cluster even though it has failed to deploy successfully. The pod continues to report **UnexpectedAdmissionError**. This issue is mitigated by the fact that application pods are typically included in a **Deployment**, **ReplicaSet**, or **DaemonSet**. If a pod is in this error state, it is of little concern because another instance should be running. Belonging to a **Deployment**, **ReplicaSet**, or **DaemonSet** guarantees the successful creation and execution of subsequent pods and ensures the successful deployment of the application.

There is ongoing work upstream to ensure that such pods are gracefully terminated. Until that work is resolved, run the following command for a single-node OpenShift cluster to remove the failed pods:

```
$ oc delete pods --field-selector status.phase=Failed -n <POD_NAMESPACE>
```



### NOTE

The option to drain the node is unavailable for single-node OpenShift clusters.

### Additional resources

- [Understanding how to evacuate pods on nodes](#)

## 6.2.5. Deleting nodes

### 6.2.5.1. Deleting nodes from a cluster

To delete a node from the OpenShift Container Platform cluster, scale down the appropriate **MachineSet** object.



### IMPORTANT

When a cluster is integrated with a cloud provider, you must delete the corresponding machine to delete a node. Do not try to use the **oc delete node** command for this task.

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



### NOTE

If you are running cluster on bare metal, you cannot delete a node by editing **MachineSet** objects. Compute machine sets are only available when a cluster is integrated with a cloud provider. Instead you must unschedule and drain the node before manually deleting it.

### Procedure

1. View the compute machine sets that are in the cluster by running the following command:

```
$ oc get machinesets -n openshift-machine-api
```

The compute machine sets are listed in the form of **<cluster-id>-worker-<aws-region-az>**.

2. Scale down the compute machine set by using one of the following methods:

- Specify the number of replicas to scale down to by running the following command:

```
$ oc scale --replicas=2 machineset <machine-set-name> -n openshift-machine-api
```

- Edit the compute machine set custom resource by running the following command:

```
$ oc edit machineset <machine-set-name> -n openshift-machine-api
```

### Example output

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  # ...
  name: <machine-set-name>
  namespace: openshift-machine-api
  # ...
spec:
  replicas: 2 1
  # ...
```

- 1** Specify the number of replicas to scale down to.

## Additional resources

- [Manually scaling a compute machine set](#)

### 6.2.5.2. Deleting nodes from a bare metal cluster

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

#### Procedure

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

1. Mark the node as unschedulable:

```
$ oc adm cordon <node_name>
```

2. Drain all pods on the node:

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

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

3. Delete the node from the cluster:

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

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

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

## 6.3. MANAGING NODES

OpenShift Container Platform uses a KubeletConfig custom resource (CR) to manage the configuration of nodes. By creating an instance of a **KubeletConfig** object, a managed machine config is created to override setting on the node.



#### NOTE

Logging in to remote machines for the purpose of changing their configuration is not supported.

### 6.3.1. Modifying nodes

To make configuration changes to a cluster, or machine pool, you must create a custom resource definition (CRD), or **kubeletConfig** object. OpenShift Container Platform uses the Machine Config Controller to watch for changes introduced through the CRD to apply the changes to the cluster.



## NOTE

Because the fields in a **kubeletConfig** object are passed directly to the kubelet from upstream Kubernetes, the validation of those fields is handled directly by the kubelet itself. Please refer to the relevant Kubernetes documentation for the valid values for these fields. Invalid values in the **kubeletConfig** object can render cluster nodes unusable.

## Procedure

1. Obtain the label associated with the static CRD, Machine Config Pool, for the type of node you want to configure. Perform one of the following steps:
  - a. Check current labels of the desired machine config pool.  
For example:

```
$ oc get machineconfigpool --show-labels
```

### Example output

```
NAME          CONFIG                                     UPDATED  UPDATING  DEGRADED
LABELS
master       rendered-master-e05b81f5ca4db1d249a1bf32f9ec24fd  True     False
False       operator.machineconfiguration.openshift.io/required-for-upgrade=
worker      rendered-worker-f50e78e1bc06d8e82327763145bfcf62  True     False
False
```

- b. Add a custom label to the desired machine config pool.  
For example:

```
$ oc label machineconfigpool worker custom-kubelet=enabled
```

2. Create a **kubeletconfig** custom resource (CR) for your configuration change.  
For example:

### Sample configuration for a custom-config CR

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: custom-config 1
spec:
  machineConfigPoolSelector:
    matchLabels:
      custom-kubelet: enabled 2
  kubeletConfig: 3
    podsPerCore: 10
    maxPods: 250
    systemReserved:
```

```
cpu: 2000m
memory: 1Gi
#...
```

- 1 Assign a name to CR.
- 2 Specify the label to apply the configuration change, this is the label you added to the machine config pool.
- 3 Specify the new value(s) you want to change.

3. Create the CR object.

```
$ oc create -f <file-name>
```

For example:

```
$ oc create -f master-kube-config.yaml
```

Most [Kubelet Configuration options](#) can be set by the user. The following options are not allowed to be overwritten:

- CgroupDriver
- ClusterDNS
- ClusterDomain
- StaticPodPath



#### NOTE

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

### 6.3.2. Updating boot images

The Machine Config Operator (MCO) uses a boot image to bring up a Red Hat Enterprise Linux CoreOS (RHCOS) node. By default, OpenShift Container Platform does not manage the boot image.

This means that the boot image in your cluster is not updated along with your cluster. For example, if your cluster was originally created with OpenShift Container Platform 4.12, the boot image that the cluster uses to create nodes is the same 4.12 version, even if your cluster is at a later version. If the cluster is later upgraded to 4.13 or later, new nodes continue to scale with the same 4.12 image.

This process could cause the following issues:

- Extra time to start up nodes
- Certificate expiration issues
- Version skew issues

To avoid these issues, you can configure your cluster to update the boot image whenever you update your cluster. By modifying the **MachineConfiguration** object, you can enable this feature. Currently, the ability to update the boot image is available for only Google Cloud Platform (GCP) clusters and is not supported for Cluster CAPI Operator managed clusters.



## IMPORTANT

The updating boot image feature 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 view the current boot image used in your cluster, examine a machine set:

### Example machine set with the boot image reference

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  name: ci-ln-hmy310k-72292-5f87z-worker-a
  namespace: openshift-machine-api
spec:
  # ...
  template:
    # ...
    spec:
      # ...
      providerSpec:
        # ...
        value:
          disks:
            - autoDelete: true
              boot: true
              image: projects/rhcos-cloud/global/images/rhcos-412-85-202203181601-0-gcp-x86-64 1
          # ...
```

- 1** This boot image is the same as the originally-installed OpenShift Container Platform version, in this example OpenShift Container Platform 4.12, regardless of the current version of the cluster. The way that the boot image is represented in the machine set depends on the platform, as the structure of the **providerSpec** field differs from platform to platform.

If you configure your cluster to update your boot images, the boot image referenced in your machine sets matches the current version of the cluster.

### Prerequisites

- You have enabled the **TechPreviewNoUpgrade** feature set by using the feature gates. For more information, see "Enabling features using feature gates" in the "Additional resources" section.

## Procedure

1. Edit the **MachineConfiguration** object, named **cluster**, to enable the updating of boot images by running the following command:

```
$ oc edit MachineConfiguration cluster
```

- a. Optional: Configure the boot image update feature for all the machine sets:

```
apiVersion: operator.openshift.io/v1
kind: MachineConfiguration
metadata:
  name: cluster
  namespace: openshift-machine-config-operator
spec:
# ...
  managedBootImages: 1
  machineManagers:
  - resource: machinesets
    apiGroup: machine.openshift.io
    selection:
      mode: All 2
```

- 1 Activates the boot image update feature.
- 2 Specifies that all the machine sets in the cluster are to be updated.

- b. Optional: Configure the boot image update feature for specific machine sets:

```
apiVersion: operator.openshift.io/v1
kind: MachineConfiguration
metadata:
  name: cluster
  namespace: openshift-machine-config-operator
spec:
# ...
  managedBootImages: 1
  machineManagers:
  - resource: machinesets
    apiGroup: machine.openshift.io
    selection:
      mode: Partial
      partial:
        machineResourceSelector:
          matchLabels:
            update-boot-image: "true" 2
```

- 1 Activates the boot image update feature.
- 2 Specifies that any machine set with this label is to be updated.



**TIP**

If an appropriate label is not present on the machine set, add a key/value pair by running a command similar to following:

```
$ oc label machineset.machine ci-ln-hmy310k-72292-5f87z-worker-a update-boot-image=true -n openshift-machine-api
```

**Verification**

1. Get the boot image version by running the following command:

```
$ oc get machinesets <machineset_name> -n openshift-machine-api -o yaml
```

**Example machine set with the boot image reference**

```
apiVersion: machine.openshift.io/v1beta1
kind: MachineSet
metadata:
  labels:
    machine.openshift.io/cluster-api-cluster: ci-ln-77hmkpt-72292-d4pxp
    update-boot-image: "true"
  name: ci-ln-77hmkpt-72292-d4pxp-worker-a
  namespace: openshift-machine-api
spec:
  # ...
  template:
    # ...
    spec:
      # ...
      providerSpec:
        # ...
        value:
          disks:
            - autoDelete: true
              boot: true
              image: projects/rhcos-cloud/global/images/rhcos-416-92-202402201450-0-gcp-x86-64
          # ...
```

- 1 This boot image is the same as the current OpenShift Container Platform version.

**Additional resources**

- [Enabling features using feature gates](#)

**6.3.2.1. Disabling updated boot images**

To disable the updated boot image feature, edit the **MachineConfiguration** object to remove the **managedBootImages** stanza.

If you disable this feature after some nodes have been created with the new boot image version, any existing nodes retain their current boot image. Turning off this feature does not rollback the nodes or

machine sets to the originally-installed boot image. The machine sets retain the boot image version that was present when the feature was enabled and is not updated again when the cluster is upgraded to a new OpenShift Container Platform version in the future.

### Procedure

1. Disable updated boot images by editing the **MachineConfiguration** object:

```
$ oc edit MachineConfiguration cluster
```

2. Remove the **managedBootImages** stanza:

```
apiVersion: operator.openshift.io/v1
kind: MachineConfiguration
metadata:
  name: cluster
  namespace: openshift-machine-config-operator
spec:
  # ...
  managedBootImages: ❶
  machineManagers:
  - resource: machinesets
    apiGroup: machine.openshift.io
    selection:
      mode: All
```

- ❶ Remove the entire stanza to disable updated boot images.

### 6.3.3. Configuring control plane nodes as schedulable

You can configure control plane nodes to be schedulable, meaning that new pods are allowed for placement on the master nodes. By default, control plane nodes are not schedulable.

You can set the masters to be schedulable, but must retain the worker nodes.



#### NOTE

You can deploy OpenShift Container Platform with no worker nodes on a bare metal cluster. In this case, the control plane nodes are marked schedulable by default.

You can allow or disallow control plane nodes to be schedulable by configuring the **mastersSchedulable** field.



#### IMPORTANT

When you configure control plane nodes from the default unschedulable to schedulable, additional subscriptions are required. This is because control plane nodes then become worker nodes.

### Procedure

1. Edit the **schedulers.config.openshift.io** resource.

■

```
$ oc edit schedulers.config.openshift.io cluster
```

2. Configure the **mastersSchedulable** field.

```
apiVersion: config.openshift.io/v1
kind: Scheduler
metadata:
  creationTimestamp: "2019-09-10T03:04:05Z"
  generation: 1
  name: cluster
  resourceVersion: "433"
  selfLink: /apis/config.openshift.io/v1/schedulers/cluster
  uid: a636d30a-d377-11e9-88d4-0a60097bee62
spec:
  mastersSchedulable: false 1
status: {}
#...
```

- 1** Set to **true** to allow control plane nodes to be schedulable, or **false** to disallow control plane nodes to be schedulable.

3. Save the file to apply the changes.

### 6.3.4. Setting SELinux booleans

OpenShift Container Platform allows you to enable and disable an SELinux boolean on a Red Hat Enterprise Linux CoreOS (RHCOS) node. The following procedure explains how to modify SELinux booleans on nodes using the Machine Config Operator (MCO). This procedure uses **container\_manage\_cgroup** as the example boolean. You can modify this value to whichever boolean you need.

#### Prerequisites

- You have installed the OpenShift CLI (oc).

#### Procedure

1. Create a new YAML file with a **MachineConfig** object, displayed in the following example:

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfig
metadata:
  labels:
    machineconfiguration.openshift.io/role: worker
  name: 99-worker-setsebool
spec:
  config:
    ignition:
      version: 3.2.0
    systemd:
      units:
        - contents: |
            [Unit]
            Description=Set SELinux booleans
```

```

Before=kubelet.service

[Service]
Type=oneshot
ExecStart=/sbin/setsebool container_manage_cgroup=on
RemainAfterExit=true

[Install]
WantedBy=multi-user.target graphical.target
enabled: true
name: setsebool.service
#...

```

2. Create the new **MachineConfig** object by running the following command:

```
$ oc create -f 99-worker-setsebool.yaml
```



#### NOTE

Applying any changes to the **MachineConfig** object causes all affected nodes to gracefully reboot after the change is applied.

### 6.3.5. Adding kernel arguments to nodes

In some special cases, you might want to add kernel arguments to a set of nodes in your cluster. This should only be done with caution and clear understanding of the implications of the arguments you set.



#### WARNING

Improper use of kernel arguments can result in your systems becoming unbootable.

Examples of kernel arguments you could set include:

- **nosmt**: Disables symmetric multithreading (SMT) in the kernel. Multithreading allows multiple logical threads for each CPU. You could consider **nosmt** in multi-tenant environments to reduce risks from potential cross-thread attacks. By disabling SMT, you essentially choose security over performance.
- **systemd.unified\_cgroup\_hierarchy**: Enables [Linux control group version 2](#) (cgroup v2). cgroup v2 is the next version of the kernel [control group](#) and offers multiple improvements.



## IMPORTANT

cgroup v1 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.

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.

- **enforcing=0**: Configures Security Enhanced Linux (SELinux) to run in permissive mode. In permissive mode, the system acts as if SELinux is enforcing the loaded security policy, including labeling objects and emitting access denial entries in the logs, but it does not actually deny any operations. While not supported for production systems, permissive mode can be helpful for debugging.



## WARNING

Disabling SELinux on RHCOS in production is not supported. Once SELinux has been disabled on a node, it must be re-provisioned before re-inclusion in a production cluster.

See [Kernel.org kernel parameters](https://kernel.org/doc/Documentation/kernel-parameters.txt) for a list and descriptions of kernel arguments.

In the following procedure, you create a **MachineConfig** object that identifies:

- A set of machines to which you want to add the kernel argument. In this case, machines with a worker role.
- Kernel arguments that are appended to the end of the existing kernel arguments.
- A label that indicates where in the list of machine configs the change is applied.

## Prerequisites

- Have administrative privilege to a working OpenShift Container Platform cluster.

## Procedure

1. List existing **MachineConfig** objects for your OpenShift Container Platform cluster to determine how to label your machine config:

```
$ oc get MachineConfig
```

## Example output

NAME	GENERATEDBYCONTROLLER
IGNITIONVERSION AGE	
00-master	52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0

```

33m
00-worker                                52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0
33m
01-master-container-runtime              52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
01-master-kubelet                        52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
01-worker-container-runtime              52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
01-worker-kubelet                        52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
99-master-generated-registries           52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
99-master-ssh                            3.2.0      40m
99-worker-generated-registries           52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
99-worker-ssh                            3.2.0      40m
rendered-master-23e785de7587df95a4b517e0647e5ab7
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0      33m
rendered-worker-5d596d9293ca3ea80c896a1191735bb1
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0      33m

```

2. Create a **MachineConfig** object file that identifies the kernel argument (for example, **05-worker-kernelarg-selinuxpermissive.yaml**)

```

apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfig
metadata:
  labels:
    machineconfiguration.openshift.io/role: worker 1
    name: 05-worker-kernelarg-selinuxpermissive 2
spec:
  kernelArguments:
    - enforcing=0 3

```

- 1** Applies the new kernel argument only to worker nodes.
- 2** Named to identify where it fits among the machine configs (05) and what it does (adds a kernel argument to configure SELinux permissive mode).
- 3** Identifies the exact kernel argument as **enforcing=0**.

3. Create the new machine config:

```
$ oc create -f 05-worker-kernelarg-selinuxpermissive.yaml
```

4. Check the machine configs to see that the new one was added:

```
$ oc get MachineConfig
```

### Example output

```

NAME                                GENERATEDBYCONTROLLER

```

```

IGNITIONVERSION AGE
00-master          52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0
33m
00-worker          52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0
33m
01-master-container-runtime      52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
01-master-kubelet      52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
01-worker-container-runtime      52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
01-worker-kubelet      52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
05-worker-kernelarg-selinuxpermissive      3.2.0      105s
99-master-generated-registries      52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
99-master-ssh      3.2.0      40m
99-worker-generated-registries      52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0      33m
99-worker-ssh      3.2.0      40m
rendered-master-23e785de7587df95a4b517e0647e5ab7
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0      33m
rendered-worker-5d596d9293ca3ea80c896a1191735bb1
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0      33m

```

5. Check the nodes:

```
$ oc get nodes
```

### Example output

```

NAME                                STATUS             ROLES    AGE  VERSION
ip-10-0-136-161.ec2.internal        Ready              worker   28m  v1.30.3
ip-10-0-136-243.ec2.internal        Ready              master   34m  v1.30.3
ip-10-0-141-105.ec2.internal        Ready,SchedulingDisabled  worker   28m  v1.30.3
ip-10-0-142-249.ec2.internal        Ready              master   34m  v1.30.3
ip-10-0-153-11.ec2.internal         Ready              worker   28m  v1.30.3
ip-10-0-153-150.ec2.internal        Ready              master   34m  v1.30.3

```

You can see that scheduling on each worker node is disabled as the change is being applied.

6. Check that the kernel argument worked by going to one of the worker nodes and listing the kernel command line arguments (in `/proc/cmdline` on the host):

```
$ oc debug node/ip-10-0-141-105.ec2.internal
```

### Example output

```

Starting pod/ip-10-0-141-105ec2internal-debug ...
To use host binaries, run `chroot /host`

sh-4.2# cat /host/proc/cmdline
BOOT_IMAGE=/ostree/rhcos-... console=tty0 console=ttyS0,115200n8
rootflags=defaults,prjquota rw root=UUID=fd0... ostree=/ostree/boot.0/rhcos/16...

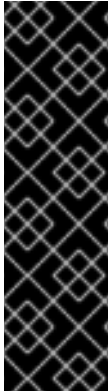
```

```
coreos.oem.id=qemu coreos.oem.id=ec2 ignition.platform.id=ec2 enforcing=0
```

```
sh-4.2# exit
```

You should see the **enforcing=0** argument added to the other kernel arguments.

### 6.3.6. Enabling swap memory use on nodes



#### IMPORTANT

Enabling swap memory use on nodes 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](#).



#### NOTE

Enabling swap memory is only available for container-native virtualization (CNV) users or use cases.



#### WARNING

Enabling swap memory can negatively impact workload performance and out-of-resource handling. Do not enable swap memory on control plane nodes.

To enable swap memory, create a **kubeletconfig** custom resource (CR) to set the **swapbehavior** parameter. You can set limited or unlimited swap memory:

- Limited: Use the **LimitedSwap** value to limit how much swap memory workloads can use. Any workloads on the node that are not managed by OpenShift Container Platform can still use swap memory. The **LimitedSwap** behavior depends on whether the node is running with Linux control groups [version 1 \(cgroups v1\)](#) or [version 2 \(cgroup v2\)](#):
  - cgroup v1: OpenShift Container Platform workloads can use any combination of memory and swap, up to the pod's memory limit, if set.
  - cgroup v2: OpenShift Container Platform workloads cannot use swap memory.
- Unlimited: Use the **UnlimitedSwap** value to allow workloads to use as much swap memory as they request, up to the system limit.

Because the kubelet will not start in the presence of swap memory without this configuration, you must enable swap memory in OpenShift Container Platform before enabling swap memory on the nodes. If there is no swap memory present on a node, enabling swap memory in OpenShift Container Platform has no effect.



## Prerequisites

- You have a running OpenShift Container Platform cluster that uses version 4.10 or later.
- You are logged in to the cluster as a user with administrative privileges.
- You have enabled the **TechPreviewNoUpgrade** feature set on the cluster (see *Nodes → Working with clusters → Enabling features using feature gates*).



### NOTE

Enabling the **TechPreviewNoUpgrade** feature set cannot be undone and prevents minor version updates. These feature sets are not recommended on production clusters.

- If cgroup v2 is enabled on a node, you must enable swap accounting on the node, by setting the **swappiness=1** kernel argument.

## Procedure

1. Apply a custom label to the machine config pool where you want to allow swap memory.

```
$ oc label machineconfigpool worker kubelet-swap=enabled
```

2. Create a custom resource (CR) to enable and configure swap settings.

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: swap-config
spec:
  machineConfigPoolSelector:
    matchLabels:
      kubelet-swap: enabled
  kubeletConfig:
    failSwapOn: false 1
    memorySwap:
      swapBehavior: LimitedSwap 2
#...
```

**1** Set to **false** to enable swap memory use on the associated nodes. Set to **true** to disable swap memory use.

**2** Specify the swap memory behavior. If unspecified, the default is **LimitedSwap**.

3. Enable swap memory on the machines.

### 6.3.7. Migrating control plane nodes from one RHOSP host to another manually

If control plane machine sets are not enabled on your cluster, you can run a script that moves a control plane node from one Red Hat OpenStack Platform (RHOSP) node to another.

**NOTE**

Control plane machine sets are not enabled on clusters that run on user-provisioned infrastructure.

For information about control plane machine sets, see "Managing control plane machines with control plane machine sets".

**Prerequisites**

- The environment variable **OS\_CLOUD** refers to a **clouds** entry that has administrative credentials in a **clouds.yaml** file.
- The environment variable **KUBECONFIG** refers to a configuration that contains administrative OpenShift Container Platform credentials.

**Procedure**

- From a command line, run the following script:

```
#!/usr/bin/env bash

set -Eeuo pipefail

if [ $# -lt 1 ]; then
  echo "Usage: '$0 node_name'"
  exit 64
fi

# Check for admin OpenStack credentials
openstack server list --all-projects >/dev/null || { >&2 echo "The script needs OpenStack admin
credentials. Exiting"; exit 77; }

# Check for admin OpenShift credentials
oc adm top node >/dev/null || { >&2 echo "The script needs OpenShift admin credentials. Exiting"; exit
77; }

set -x

declare -r node_name="$1"
declare server_id
server_id="$(openstack server list --all-projects -f value -c ID -c Name | grep "$node_name" | cut -d' '
-f1)"
readonly server_id

# Drain the node
oc adm cordon "$node_name"
oc adm drain "$node_name" --delete-emptydir-data --ignore-daemonsets --force

# Power off the server
oc debug "node/${node_name}" -- chroot /host shutdown -h 1

# Verify the server is shut off
until openstack server show "$server_id" -f value -c status | grep -q 'SHUTOFF'; do sleep 5; done

# Migrate the node
```

```

openstack server migrate --wait "$server_id"

# Resize the VM
openstack server resize confirm "$server_id"

# Wait for the resize confirm to finish
until openstack server show "$server_id" -f value -c status | grep -q 'SHUTOFF'; do sleep 5; done

# Restart the VM
openstack server start "$server_id"

# Wait for the node to show up as Ready:
until oc get node "$node_name" | grep -q "^${node_name}[:space:]+\+Ready"; do sleep 5; done

# Uncordon the node
oc adm uncordon "$node_name"

# Wait for cluster operators to stabilize
until oc get co -o go-template='status: {{ range .items }}{{ range .status.conditions }}{{ if eq .type "Degraded" }}{{ if ne .status "False" }}DEGRADED{{ end }}{{ else if eq .type "Progressing" }}{{ if ne .status "False" }}PROGRESSING{{ end }}{{ else if eq .type "Available" }}{{ if ne .status "True" }}NOTAVAILABLE{{ end }}{{ end }}{{ end }}' | grep -qv '\(DEGRADED\|PROGRESSING\|NOTAVAILABLE\)'; do sleep 5; done

```

If the script completes, the control plane machine is migrated to a new RHOSP node.

#### Additional resources

- [Managing control plane machines with control plane machine sets](#)

## 6.4. ADDING WORKER NODES TO AN ON-PREMISE CLUSTER

For on-premise clusters, you can add worker nodes by using the [OpenShift CLI \(oc\)](#) to generate an ISO image, which can then be used to boot one or more nodes in your target cluster. This process can be used regardless of how you installed your cluster.

You can add one or more nodes at a time while customizing each node with more complex configurations, such as static network configuration, or you can specify only the MAC address of each node. Any required configurations that are not specified during ISO generation are retrieved from the target cluster and applied to the new nodes.

Preflight validation checks are also performed when booting the ISO image to inform you of failure-causing issues before you attempt to boot each node.

### 6.4.1. Supported platforms

The following platforms are supported for this method of adding nodes:

- **baremetal**
- **vsphere**
- **none**
- **external**

## 6.4.2. Adding nodes to your cluster

You can add nodes with this method in the following two ways:

- Adding one or more nodes using a configuration file.  
You can specify configurations for one or more nodes in the **nodes-config.yaml** file before running the **oc adm node-image create** command. This is useful if you want to add more than one node at a time, or if you are specifying complex configurations.
- Adding a single node using only command flags.  
You can add a node by running the **oc adm node-image create** command with flags to specify your configurations. This is useful if you want to add only a single node at a time, and have only simple configurations to specify for that node.

### 6.4.2.1. Adding one or more nodes using a configuration file

You can add one or more nodes to your cluster by using the **nodes-config.yaml** file to specify configurations for the new nodes.

#### Prerequisites

- You have installed the OpenShift CLI (**oc**)
- You have an active connection to your target cluster
- You have a kubeconfig file available

#### Procedure

1. Create a new YAML file that contains configurations for the nodes you are adding and is named **nodes-config.yaml**. You must provide a MAC address for each new node.  
In the following example file, two new workers are described with an initial static network configuration:

#### Example nodes-config.yaml file

```
hosts:
- hostname: extra-worker-1
  rootDeviceHints:
    deviceName: /dev/sda
  interfaces:
  - macAddress: 00:00:00:00:00:00
    name: eth0
  networkConfig:
    interfaces:
    - name: eth0
      type: ethernet
      state: up
      mac-address: 00:00:00:00:00:00
    ipv4:
      enabled: true
      address:
      - ip: 192.168.122.2
        prefix-length: 23
      dhcp: false
```

```

- hostname: extra-worker-2
  rootDeviceHints:
    deviceName: /dev/sda
  interfaces:
    - macAddress: 00:00:00:00:00:02
      name: eth0
  networkConfig:
    interfaces:
      - name: eth0
        type: ethernet
        state: up
        mac-address: 00:00:00:00:00:02
    ipv4:
      enabled: true
      address:
        - ip: 192.168.122.3
          prefix-length: 23
      dhcp: false

```

2. Generate the ISO image by running the following command:

```
$ oc adm node-image create nodes-config.yaml
```



### IMPORTANT

In order for the **create** command to fetch a release image that matches the target cluster version, you must specify a valid pull secret. You can specify the pull secret either by using the **--registry-config** flag or by setting the **REGISTRY\_AUTH\_FILE** environment variable beforehand.



### NOTE

If the directory of the **nodes-config.yaml** file is not specified by using the **--dir** flag, the tool looks for the file in the current directory.

3. Verify that a new **node.<arch>.iso** file is present in the asset directory. The asset directory is your current directory, unless you specified a different one when creating the ISO image.
4. Boot the selected node with the generated ISO image.
5. Track progress of the node creation by running the following command:

```
$ oc adm node-image monitor <ip_addresses>
```

where:

**<ip\_addresses>**

Specifies a list of the IP addresses of the nodes that are being added.

**NOTE**

If reverse DNS entries are not available for your node, the **oc adm node-image monitor** command skips checks for pending certificate signing requests (CSRs). If these checks are skipped, you must manually check for CSRs by running the **oc get csr** command.

6. Approve the CSRs by running the following command for each CSR:

```
$ oc adm certificate approve <csr_name>
```

**6.4.2.2. Adding a node with command flags**

You can add a single node to your cluster by using command flags to specify configurations for the new node.

**Prerequisites**

- You have installed the OpenShift CLI (**oc**)
- You have an active connection to your target cluster
- You have a kubeconfig file available

**Procedure**

1. Generate the ISO image by running the following command. The MAC address must be specified using a command flag. See the "Cluster configuration reference" section for more flags that you can use with this command.

```
$ oc adm node-image create --mac-address=<mac_address>
```

where:

**<mac\_address>**

Specifies the MAC address of the node that is being added.

**IMPORTANT**

In order for the **create** command to fetch a release image that matches the target cluster version, you must specify a valid pull secret. You can specify the pull secret either by using the **--registry-config** flag or by setting the **REGISTRY\_AUTH\_FILE** environment variable beforehand.

**TIP**

To see additional flags that can be used to configure your node, run the following **oc adm node-image create --help** command.

2. Verify that a new **node.<arch>.iso** file is present in the asset directory. The asset directory is your current directory, unless you specified a different one when creating the ISO image.

3. Boot the node with the generated ISO image.
4. Track progress of the node creation by running the following command:

```
$ oc adm node-image monitor <ip_address>
```

where:

**<ip\_address>**

Specifies a list of the IP addresses of the nodes that are being added.



#### NOTE

If reverse DNS entries are not available for your node, the **oc adm node-image monitor** command skips checks for pending certificate signing requests (CSRs). If these checks are skipped, you must manually check for CSRs by running the **oc get csr** command.

5. Approve the pending CSRs by running the following command for each CSR:

```
$ oc adm certificate approve <csr_name>
```

### 6.4.3. Cluster configuration reference

When creating the ISO image, configurations are retrieved from the target cluster and are applied to the new nodes. Any configurations for your cluster are applied to the nodes unless you override the configurations in either the **nodes-config.yaml** file or any flags you add to the **oc adm node-image create** command.

#### 6.4.3.1. YAML file parameters

Configuration parameters that can be specified in the **nodes-config.yaml** file are described in the following table:

**Table 6.2. nodes-config.yaml parameters**

Parameter	Description	Values
<b>hosts:</b>	Host configuration.	An array of host configuration objects.
<b>hosts: hostname:</b>	Hostname. Overrides the hostname obtained from either the Dynamic Host Configuration Protocol (DHCP) or a reverse DNS lookup. Each host must have a unique hostname supplied by one of these methods, although configuring a hostname through this parameter is optional.	String.

Parameter	Description	Values
<b>hosts:</b> <b>interfaces:</b>	Provides a table of the name and MAC address mappings for the interfaces on the host. If a <b>NetworkConfig</b> section is provided in the <b>nodes-config.yaml</b> file, this table must be included and the values must match the mappings provided in the <b>NetworkConfig</b> section.	An array of host configuration objects.
<b>hosts:</b> <b>interfaces:</b> <b>name:</b>	The name of an interface on the host.	String.
<b>hosts:</b> <b>interfaces:</b> <b>macAddress:</b>	The MAC address of an interface on the host.	A MAC address such as the following example: <b>00-B0-D0-63-C2-26</b> .
<b>hosts:</b> <b>rootDeviceHints:</b>	Enables provisioning of the Red Hat Enterprise Linux CoreOS (RHCOS) image to a particular device. The node-adding tool examines the devices in the order it discovers them, and compares the discovered values with the hint values. It uses the first discovered device that matches the hint value.	A dictionary of key-value pairs. For more information, see "Root device hints" in the "Setting up the environment for an OpenShift installation" page.
<b>hosts:</b> <b>rootDeviceHints:</b> <b>deviceName:</b>	The name of the device the RHCOS image is provisioned to.	String.
<b>hosts:</b> <b>networkConfig:</b>	The host network definition. The configuration must match the Host Network Management API defined in the <a href="#">nmstate documentation</a> .	A dictionary of host network configuration objects.

### 6.4.3.2. Command flag options

You can use command flags with the **oc adm node-image create** command to configure the nodes you are creating.

The following table describes command flags that are not limited to the single-node use case:



Table 6.3. General command flags

Flag	Description	Values
<b>--certificate-authority</b>	The path to a certificate authority bundle to use when communicating with the managed container image registries. If the <b>-insecure</b> flag is used, this flag is ignored.	String
<b>--dir</b>	The path containing the configuration file, if provided. This path is also used to store the generated artifacts.	String
<b>--insecure</b>	Allows push and pull operations to registries to be made over HTTP.	Boolean
<b>-o, --output-name</b>	The name of the generated output image.	String
<b>-a, --registry-config</b>	The path to your registry credentials. Alternatively, you can specify the <b>REGISTRY_AUTH_FILE</b> environment variable. The default paths are <b>`\${XDG_RUNTIME_DIR}/containers/auth.json</b> , <b>`\${XDG_RUNTIME_DIR}/run/containers/\${UID}/auth.json</b> , <b>`\${XDG_CONFIG_HOME}/containers/auth.json</b> , <b>`\${DOCKER_CONFIG}</b> , <b>`\${HOME}/.docker/config.json</b> , <b>`\${HOME}/.dockercfg</b> . The order can be changed through the deprecated <b>REGISTRY_AUTH_PREFERENCE</b> environment variable to a "docker" value, in order to prioritize Docker credentials over Podman.	String
<b>--skip-verification</b>	An option to skip verifying the integrity of the retrieved content. This is not recommended, but might be necessary when importing images from older image registries. Bypass verification only if the registry is known to be trustworthy.	Boolean

The following table describes command flags that can be used only when creating a single node:

**Table 6.4. Single-node only command flags**

Flag	Description	Values
<b>-c, --cpu-architecture</b>	The CPU architecture to be used to install the node. This flag can be used to create only a single node, and the <b>--mac-address</b> flag must be defined.	String
<b>--hostname</b>	The hostname to be set for the node. This flag can be used to create only a single node, and the <b>--mac-address</b> flag must be defined.	String
<b>-m, --mac-address</b>	The MAC address used to identify the host to apply configurations to. This flag can be used to create only a single node, and the <b>--mac-address</b> flag must be defined.	String
<b>--network-config-path</b>	The path to a YAML file containing NMState configurations to be applied to the node. This flag can be used to create only a single node, and the <b>--mac-address</b> flag must be defined.	String
<b>--root-device-hint</b>	A hint for specifying the storage location for the image root filesystem. The accepted format is <b>&lt;hint_name&gt;:&lt;value&gt;</b> . This flag can be used to create only a single node, and the <b>--mac-address</b> flag must be defined.	String
<b>-k, --ssh-key-path</b>	The path to the SSH key used to access the node. This flag can be used to create only a single node, and the <b>--mac-address</b> flag must be defined.	String

#### Additional resources

- [Root device hints](#)

## 6.5. MANAGING THE MAXIMUM NUMBER OF PODS PER NODE

In OpenShift Container Platform, you can configure the number of pods that can run on a node based on the number of processor cores on the node, a hard limit or both. If you use both options, the lower of the two limits the number of pods on a node.

When both options are in use, the lower of the two values limits the number of pods on a node. Exceeding these values can result in:

- Increased CPU utilization.
- Slow pod scheduling.
- Potential out-of-memory scenarios, depending on the amount of memory in the node.
- Exhausting the pool of IP addresses.
- Resource overcommitting, leading to poor user application performance.



### IMPORTANT

In Kubernetes, a pod that is holding a single container actually uses two containers. The second container is used to set up networking prior to the actual container starting. Therefore, a system running 10 pods will actually have 20 containers running.



### NOTE

Disk IOPS throttling from the cloud provider might have an impact on CRI-O and kubelet. They might get overloaded when there are large number of I/O intensive pods running on the nodes. It is recommended that you monitor the disk I/O on the nodes and use volumes with sufficient throughput for the workload.

The  **podsPerCore**  parameter sets the number of pods the node can run based on the number of processor cores on the node. For example, if  **podsPerCore**  is set to  **10**  on a node with 4 processor cores, the maximum number of pods allowed on the node will be  **40** .

```
kubeletConfig:
  podsPerCore: 10
```

Setting  **podsPerCore**  to  **0**  disables this limit. The default is  **0** . The value of the  **podsPerCore**  parameter cannot exceed the value of the  **maxPods**  parameter.

The  **maxPods**  parameter sets the number of pods the node can run to a fixed value, regardless of the properties of the node.

```
kubeletConfig:
  maxPods: 250
```

## 6.5.1. Configuring the maximum number of pods per node

Two parameters control the maximum number of pods that can be scheduled to a node:  **podsPerCore**  and  **maxPods** . If you use both options, the lower of the two limits the number of pods on a node.

For example, if  **podsPerCore**  is set to  **10**  on a node with 4 processor cores, the maximum number of pods allowed on the node will be 40.

## Prerequisites

1. Obtain the label associated with the static **MachineConfigPool** CRD for the type of node you want to configure by entering the following command:

```
$ oc edit machineconfigpool <name>
```

For example:

```
$ oc edit machineconfigpool worker
```

## Example output

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfigPool
metadata:
  creationTimestamp: "2022-11-16T15:34:25Z"
  generation: 4
  labels:
    pools.operator.machineconfiguration.openshift.io/worker: "" 1
  name: worker
#...
```

- 1 The label appears under Labels.

## TIP

If the label is not present, add a key/value pair such as:

```
$ oc label machineconfigpool worker custom-kubelet=small-pods
```

## Procedure

1. Create a custom resource (CR) for your configuration change.

### Sample configuration for a max-pods CR

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: set-max-pods 1
spec:
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" 2
  kubeletConfig:
    podsPerCore: 10 3
    maxPods: 250 4
#...
```

- 1 Assign a name to CR.

- 2 Specify the label from the machine config pool.
- 3 Specify the number of pods the node can run based on the number of processor cores on the node.
- 4 Specify the number of pods the node can run to a fixed value, regardless of the properties of the node.

**NOTE**

Setting **PodsPerCore** to **0** disables this limit.

In the above example, the default value for **PodsPerCore** is **10** and the default value for **maxPods** is **250**. This means that unless the node has 25 cores or more, by default, **PodsPerCore** will be the limiting factor.

2. Run the following command to create the CR:

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

**Verification**

1. List the **MachineConfigPool** CRDs to see if the change is applied. The **UPDATING** column reports **True** if the change is picked up by the Machine Config Controller:

```
$ oc get machineconfigpools
```

**Example output**

```
NAME      CONFIG                                UPDATED  UPDATING  DEGRADED
master   master-9cc2c72f205e103bb534         False   False    False
worker   worker-8cecd1236b33ee3f8a5e         False   True     False
```

Once the change is complete, the **UPDATED** column reports **True**.

```
$ oc get machineconfigpools
```

**Example output**

```
NAME      CONFIG                                UPDATED  UPDATING  DEGRADED
master   master-9cc2c72f205e103bb534         False   True     False
worker   worker-8cecd1236b33ee3f8a5e         True    False    False
```

## 6.6. USING THE NODE TUNING OPERATOR

Learn about the Node Tuning Operator and how you can use it to manage node-level tuning by orchestrating the tuned daemon.

**Purpose**

The Node Tuning Operator helps you manage node-level tuning by orchestrating the TuneD daemon and achieves low latency performance by using the Performance Profile controller. The majority of high-

performance applications require some level of kernel tuning. The Node Tuning Operator provides a unified management interface to users of node-level sysctls and more flexibility to add custom tuning specified by user needs.

The Operator manages the containerized TuneD daemon for OpenShift Container Platform as a Kubernetes daemon set. It ensures the custom tuning specification is passed to all containerized TuneD daemons running in the cluster in the format that the daemons understand. The daemons run on all nodes in the cluster, one per node.

Node-level settings applied by the containerized TuneD daemon are rolled back on an event that triggers a profile change or when the containerized TuneD daemon is terminated gracefully by receiving and handling a termination signal.

The Node Tuning Operator uses the Performance Profile controller to implement automatic tuning to achieve low latency performance for OpenShift Container Platform applications.

The cluster administrator configures a performance profile to define node-level settings such as the following:

- Updating the kernel to kernel-rt.
- Choosing CPUs for housekeeping.
- Choosing CPUs for running workloads.

The Node Tuning Operator is part of a standard OpenShift Container Platform installation in version 4.1 and later.



#### NOTE

In earlier versions of OpenShift Container Platform, the Performance Addon Operator was used to implement automatic tuning to achieve low latency performance for OpenShift applications. In OpenShift Container Platform 4.11 and later, this functionality is part of the Node Tuning Operator.

### 6.6.1. Accessing an example Node Tuning Operator specification

Use this process to access an example Node Tuning Operator specification.

#### Procedure

- Run the following command to access an example Node Tuning Operator specification:

```
oc get tuned.tuned.openshift.io/default -o yaml -n openshift-cluster-node-tuning-operator
```

The default CR is meant for delivering standard node-level tuning for the OpenShift Container Platform platform and it can only be modified to set the Operator Management state. Any other custom changes to the default CR will be overwritten by the Operator. For custom tuning, create your own Tuned CRs. Newly created CRs will be combined with the default CR and custom tuning applied to OpenShift Container Platform nodes based on node or pod labels and profile priorities.



## WARNING

While in certain situations the support for pod labels can be a convenient way of automatically delivering required tuning, this practice is discouraged and strongly advised against, especially in large-scale clusters. The default Tuned CR ships without pod label matching. If a custom profile is created with pod label matching, then the functionality will be enabled at that time. The pod label functionality will be deprecated in future versions of the Node Tuning Operator.

### 6.6.2. Custom tuning specification

The custom resource (CR) for the Operator has two major sections. The first section, **profile:**, is a list of Tuned profiles and their names. The second, **recommend:**, defines the profile selection logic.

Multiple custom tuning specifications can co-exist as multiple CRs in the Operator's namespace. The existence of new CRs or the deletion of old CRs is detected by the Operator. All existing custom tuning specifications are merged and appropriate objects for the containerized Tuned daemons are updated.

#### Management state

The Operator Management state is set by adjusting the default Tuned CR. By default, the Operator is in the Managed state and the **spec.managementState** field is not present in the default Tuned CR. Valid values for the Operator Management state are as follows:

- Managed: the Operator will update its operands as configuration resources are updated
- Unmanaged: the Operator will ignore changes to the configuration resources
- Removed: the Operator will remove its operands and resources the Operator provisioned

#### Profile data

The **profile:** section lists Tuned profiles and their names.

```
profile:
- name: tuned_profile_1
  data: |
    # Tuned profile specification
    [main]
    summary=Description of tuned_profile_1 profile

    [sysctl]
    net.ipv4.ip_forward=1
    # ... other sysctl's or other Tuned daemon plugins supported by the containerized Tuned

# ...

- name: tuned_profile_n
  data: |
    # Tuned profile specification
    [main]
```

```
summary=Description of tuned_profile_n profile
```

```
# tuned_profile_n profile settings
```

## Recommended profiles

The **profile:** selection logic is defined by the **recommend:** section of the CR. The **recommend:** section is a list of items to recommend the profiles based on a selection criteria.

```
recommend:
<recommend-item-1>
# ...
<recommend-item-n>
```

The individual items of the list:

```
- machineConfigLabels: ❶
  <mcLabels> ❷
  match: ❸
  <match> ❹
  priority: <priority> ❺
  profile: <tuned_profile_name> ❻
  operand: ❼
  debug: <bool> ❽
  tunedConfig:
    reapply_sysctl: <bool> ❾
```

- ❶ Optional.
- ❷ A dictionary of key/value **MachineConfig** labels. The keys must be unique.
- ❸ If omitted, profile match is assumed unless a profile with a higher priority matches first or **machineConfigLabels** is set.
- ❹ An optional list.
- ❺ Profile ordering priority. Lower numbers mean higher priority (**0** is the highest priority).
- ❻ A TuneD profile to apply on a match. For example **tuned\_profile\_1**.
- ❼ Optional operand configuration.
- ❽ Turn debugging on or off for the TuneD daemon. Options are **true** for on or **false** for off. The default is **false**.
- ❾ Turn **reapply\_sysctl** functionality on or off for the TuneD daemon. Options are **true** for on and **false** for off.

**<match>** is an optional list recursively defined as follows:

```
- label: <label_name> ❶
  value: <label_value> ❷
  type: <label_type> ❸
```



`<match>` 4

- 1 Node or pod label name.
- 2 Optional node or pod label value. If omitted, the presence of `<label_name>` is enough to match.
- 3 Optional object type (**node** or **pod**). If omitted, **node** is assumed.
- 4 An optional `<match>` list.

If `<match>` is not omitted, all nested `<match>` sections must also evaluate to **true**. Otherwise, **false** is assumed and the profile with the respective `<match>` section will not be applied or recommended. Therefore, the nesting (child `<match>` sections) works as logical AND operator. Conversely, if any item of the `<match>` list matches, the entire `<match>` list evaluates to **true**. Therefore, the list acts as logical OR operator.

If `machineConfigLabels` is defined, machine config pool based matching is turned on for the given **recommend**: list item. `<mcLabels>` specifies the labels for a machine config. The machine config is created automatically to apply host settings, such as kernel boot parameters, for the profile `<tuned_profile_name>`. This involves finding all machine config pools with machine config selector matching `<mcLabels>` and setting the profile `<tuned_profile_name>` on all nodes that are assigned the found machine config pools. To target nodes that have both master and worker roles, you must use the master role.

The list items `match` and `machineConfigLabels` are connected by the logical OR operator. The `match` item is evaluated first in a short-circuit manner. Therefore, if it evaluates to **true**, the `machineConfigLabels` item is not considered.



### IMPORTANT

When using machine config pool based matching, it is advised to group nodes with the same hardware configuration into the same machine config pool. Not following this practice might result in TuneD operands calculating conflicting kernel parameters for two or more nodes sharing the same machine config pool.

### Example: Node or pod label based matching

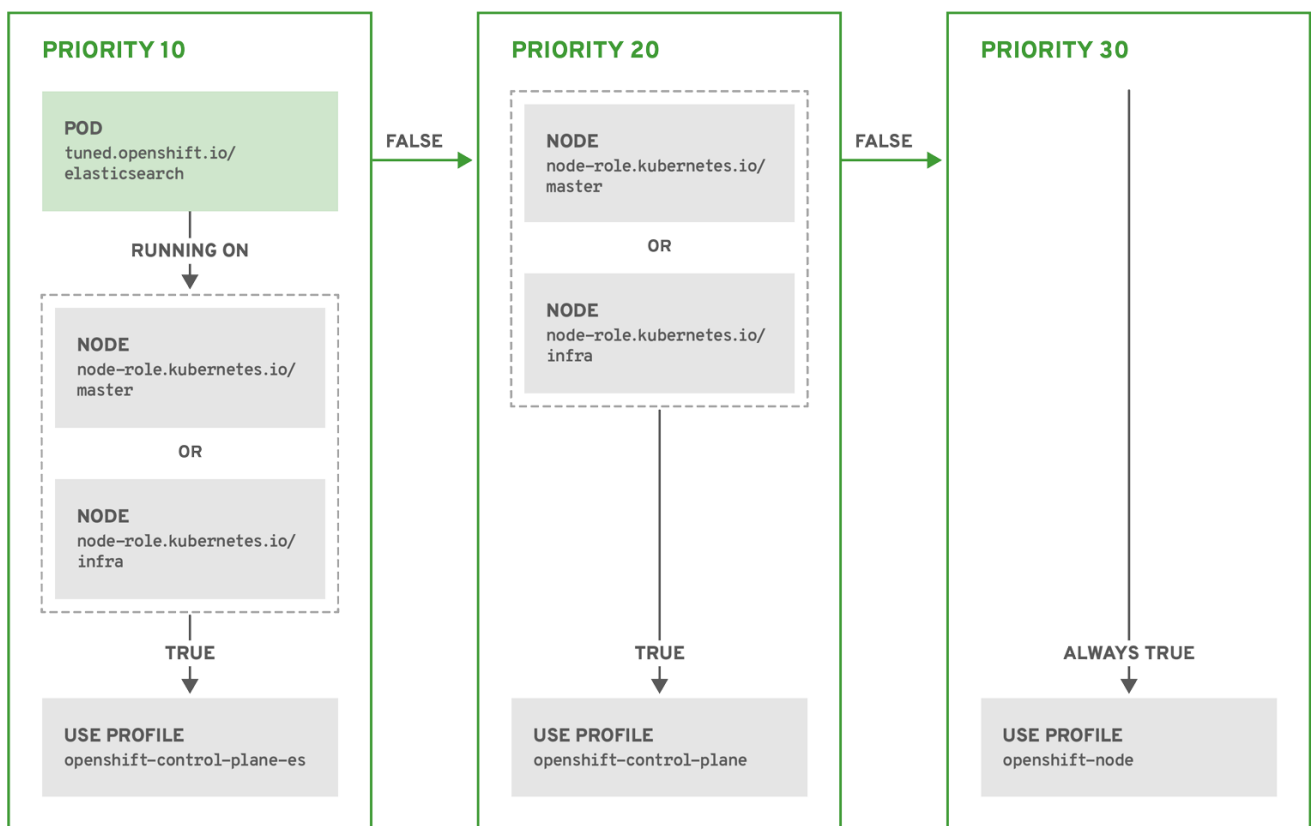
```
- match:
- label: tuned.openshift.io/elasticsearch
  match:
  - label: node-role.kubernetes.io/master
  - label: node-role.kubernetes.io/infra
  type: pod
  priority: 10
  profile: openshift-control-plane-es
- match:
  - label: node-role.kubernetes.io/master
  - label: node-role.kubernetes.io/infra
  priority: 20
  profile: openshift-control-plane
- priority: 30
  profile: openshift-node
```

The CR above is translated for the containerized TuneD daemon into its `recommend.conf` file based on

the profile priorities. The profile with the highest priority (**10**) is **openshift-control-plane-es** and, therefore, it is considered first. The containerized TuneD daemon running on a given node looks to see if there is a pod running on the same node with the **tuned.openshift.io/elasticsearch** label set. If not, the entire **<match>** section evaluates as **false**. If there is such a pod with the label, in order for the **<match>** section to evaluate to **true**, the node label also needs to be **node-role.kubernetes.io/master** or **node-role.kubernetes.io/infra**.

If the labels for the profile with priority **10** matched, **openshift-control-plane-es** profile is applied and no other profile is considered. If the node/pod label combination did not match, the second highest priority profile (**openshift-control-plane**) is considered. This profile is applied if the containerized TuneD pod runs on a node with labels **node-role.kubernetes.io/master** or **node-role.kubernetes.io/infra**.

Finally, the profile **openshift-node** has the lowest priority of **30**. It lacks the **<match>** section and, therefore, will always match. It acts as a profile catch-all to set **openshift-node** profile, if no other profile with higher priority matches on a given node.



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### Example: Machine config pool based matching

```

apiVersion: tuned.openshift.io/v1
kind: Tuned
metadata:
  name: openshift-node-custom
  namespace: openshift-cluster-node-tuning-operator
spec:
  profile:
    - data: |
      [main]
      summary=Custom OpenShift node profile with an additional kernel parameter
  
```

```

include=openshift-node
[bootloader]
cmdline_openshift_node_custom=+skew_tick=1
name: openshift-node-custom

recommend:
- machineConfigLabels:
  machineconfiguration.openshift.io/role: "worker-custom"
priority: 20
profile: openshift-node-custom

```

To minimize node reboots, label the target nodes with a label the machine config pool's node selector will match, then create the Tuned CR above and finally create the custom machine config pool itself.

### Cloud provider-specific TuneD profiles

With this functionality, all Cloud provider-specific nodes can conveniently be assigned a TuneD profile specifically tailored to a given Cloud provider on a OpenShift Container Platform cluster. This can be accomplished without adding additional node labels or grouping nodes into machine config pools.

This functionality takes advantage of **spec.providerID** node object values in the form of **<cloud-provider>://<cloud-provider-specific-id>** and writes the file **/var/lib/ocp-tuned/provider** with the value **<cloud-provider>** in NTO operand containers. The content of this file is then used by TuneD to load **provider-<cloud-provider>** profile if such profile exists.

The **openshift** profile that both **openshift-control-plane** and **openshift-node** profiles inherit settings from is now updated to use this functionality through the use of conditional profile loading. Neither NTO nor TuneD currently include any Cloud provider-specific profiles. However, it is possible to create a custom profile **provider-<cloud-provider>** that will be applied to all Cloud provider-specific cluster nodes.

### Example GCE Cloud provider profile

```

apiVersion: tuned.openshift.io/v1
kind: Tuned
metadata:
  name: provider-gce
  namespace: openshift-cluster-node-tuning-operator
spec:
  profile:
  - data: |
    [main]
    summary=GCE Cloud provider-specific profile
    # Your tuning for GCE Cloud provider goes here.
    name: provider-gce

```



#### NOTE

Due to profile inheritance, any setting specified in the **provider-<cloud-provider>** profile will be overwritten by the **openshift** profile and its child profiles.

### 6.6.3. Default profiles set on a cluster

The following are the default profiles set on a cluster.

```

apiVersion: tuned.openshift.io/v1
kind: Tuned
metadata:
  name: default
  namespace: openshift-cluster-node-tuning-operator
spec:
  profile:
    - data: |
      [main]
      summary=Optimize systems running OpenShift (provider specific parent profile)
      include=-provider-$(f:exec:cat:/var/lib/ocp-tuned/provider},openshift
      name: openshift
  recommend:
    - profile: openshift-control-plane
      priority: 30
      match:
        - label: node-role.kubernetes.io/master
        - label: node-role.kubernetes.io/infra
    - profile: openshift-node
      priority: 40

```

Starting with OpenShift Container Platform 4.9, all OpenShift Tuned profiles are shipped with the Tuned package. You can use the **oc exec** command to view the contents of these profiles:

```

$ oc exec $tuned_pod -n openshift-cluster-node-tuning-operator -- find /usr/lib/tuned/openshift{,-control-plane,-node} -name tuned.conf -exec grep -H ^ {} \;

```

#### 6.6.4. Supported Tuned daemon plugins

Excluding the **[main]** section, the following Tuned plugins are supported when using custom profiles defined in the **profile:** section of the Tuned CR:

- audio
- cpu
- disk
- eeepc\_she
- modules
- mounts
- net
- scheduler
- scsi\_host
- selinux
- sysctl
- sysfs

- usb
- video
- vm
- bootloader

There is some dynamic tuning functionality provided by some of these plugins that is not supported. The following TuneD plugins are currently not supported:

- script
- systemd



#### NOTE

The TuneD bootloader plugin only supports Red Hat Enterprise Linux CoreOS (RHCOS) worker nodes.

#### Additional resources

- [Available TuneD Plugins](#)
- [Getting Started with TuneD](#)

## 6.7. REMEDIATING, FENCING, AND MAINTAINING NODES

When node-level failures occur, such as the kernel hangs or network interface controllers (NICs) fail, the work required from the cluster does not decrease, and workloads from affected nodes need to be restarted somewhere. Failures affecting these workloads risk data loss, corruption, or both. It is important to isolate the node, known as **fencing**, before initiating recovery of the workload, known as **remediation**, and recovery of the node.

For more information on remediation, fencing, and maintaining nodes, see the [Workload Availability for Red Hat OpenShift](#) documentation.

## 6.8. UNDERSTANDING NODE REBOOTING

To reboot a node without causing an outage for applications running on the platform, it is important to first evacuate the pods. For pods that are made highly available by the routing tier, nothing else needs to be done. For other pods needing storage, typically databases, it is critical to ensure that they can remain in operation with one pod temporarily going offline. While implementing resiliency for stateful pods is different for each application, in all cases it is important to configure the scheduler to use node anti-affinity to ensure that the pods are properly spread across available nodes.

Another challenge is how to handle nodes that are running critical infrastructure such as the router or the registry. The same node evacuation process applies, though it is important to understand certain edge cases.

### 6.8.1. About rebooting nodes running critical infrastructure

When rebooting nodes that host critical OpenShift Container Platform infrastructure components, such as router pods, registry pods, and monitoring pods, ensure that there are at least three nodes available to run these components.

The following scenario demonstrates how service interruptions can occur with applications running on OpenShift Container Platform when only two nodes are available:

- Node A is marked unschedulable and all pods are evacuated.
- The registry pod running on that node is now redeployed on node B. Node B is now running both registry pods.
- Node B is now marked unschedulable and is evacuated.
- The service exposing the two pod endpoints on node B loses all endpoints, for a brief period of time, until they are redeployed to node A.

When using three nodes for infrastructure components, this process does not result in a service disruption. However, due to pod scheduling, the last node that is evacuated and brought back into rotation does not have a registry pod. One of the other nodes has two registry pods. To schedule the third registry pod on the last node, use pod anti-affinity to prevent the scheduler from locating two registry pods on the same node.

### Additional information

- For more information on pod anti-affinity, see [Placing pods relative to other pods using affinity and anti-affinity rules](#).

## 6.8.2. Rebooting a node using pod anti-affinity

Pod anti-affinity is slightly different than node anti-affinity. Node anti-affinity can be violated if there are no other suitable locations to deploy a pod. Pod anti-affinity can be set to either required or preferred.

With this in place, if only two infrastructure nodes are available and one is rebooted, the container image registry pod is prevented from running on the other node. **oc get pods** reports the pod as unready until a suitable node is available. Once a node is available and all pods are back in ready state, the next node can be restarted.

### Procedure

To reboot a node using pod anti-affinity:

1. Edit the node specification to configure pod anti-affinity:

```
apiVersion: v1
kind: Pod
metadata:
  name: with-pod-antiaffinity
spec:
  affinity:
    podAntiAffinity: 1
      preferredDuringSchedulingIgnoredDuringExecution: 2
        - weight: 100 3
          podAffinityTerm:
            labelSelector:
              matchExpressions:
                - key: registry 4
                  operator: In 5
                  values:
```

```

- default
topologyKey: kubernetes.io/hostname
#...
```

- 1 Stanza to configure pod anti-affinity.
- 2 Defines a preferred rule.
- 3 Specifies a weight for a preferred rule. The node with the highest weight is preferred.
- 4 Description of the pod label that determines when the anti-affinity rule applies. Specify a key and value for the label.
- 5 The operator represents the relationship between the label on the existing pod and the set of values in the **matchExpression** parameters in the specification for the new pod. Can be **In**, **NotIn**, **Exists**, or **DoesNotExist**.

This example assumes the container image registry pod has a label of **registry=default**. Pod anti-affinity can use any Kubernetes match expression.

2. Enable the **MatchInterPodAffinity** scheduler predicate in the scheduling policy file.
3. Perform a graceful restart of the node.

### 6.8.3. Understanding how to reboot nodes running routers

In most cases, a pod running an OpenShift Container Platform router exposes a host port.

The **PodFitsPorts** scheduler predicate ensures that no router pods using the same port can run on the same node, and pod anti-affinity is achieved. If the routers are relying on IP failover for high availability, there is nothing else that is needed.

For router pods relying on an external service such as AWS Elastic Load Balancing for high availability, it is that service's responsibility to react to router pod restarts.

In rare cases, a router pod may not have a host port configured. In those cases, it is important to follow the recommended restart process for infrastructure nodes.

### 6.8.4. Rebooting a node gracefully

Before rebooting a node, it is recommended to backup etcd data to avoid any data loss on the node.



#### NOTE

For single-node OpenShift clusters that require users to perform the **oc login** command rather than having the certificates in **kubeconfig** file to manage the cluster, the **oc adm** commands might not be available after cordoning and draining the node. This is because the **openshift-oauth-apiserver** pod is not running due to the cordon. You can use SSH to access the nodes as indicated in the following procedure.

In a single-node OpenShift cluster, pods cannot be rescheduled when cordoning and draining. However, doing so gives the pods, especially your workload pods, time to properly stop and release associated resources.

## Procedure

To perform a graceful restart of a node:

1. Mark the node as unschedulable:

```
$ oc adm cordon <node1>
```

2. Drain the node to remove all the running pods:

```
$ oc adm drain <node1> --ignore-daemonsets --delete-emptydir-data --force
```

You might receive errors that pods associated with custom pod disruption budgets (PDB) cannot be evicted.

### Example error

```
error when evicting pods/"rails-postgresql-example-1-72v2w" -n "rails" (will retry after 5s):  
Cannot evict pod as it would violate the pod's disruption budget.
```

In this case, run the drain command again, adding the **disable-eviction** flag, which bypasses the PDB checks:

```
$ oc adm drain <node1> --ignore-daemonsets --delete-emptydir-data --force --disable-  
eviction
```

3. Access the node in debug mode:

```
$ oc debug node/<node1>
```

4. Change your root directory to **/host**:

```
$ chroot /host
```

5. Restart the node:

```
$ systemctl reboot
```

In a moment, the node enters the **NotReady** state.



### NOTE

With some single-node OpenShift clusters, the **oc** commands might not be available after you cordon and drain the node because the **openshift-oauth-apiserver** pod is not running. You can use SSH to connect to the node and perform the reboot.

```
$ ssh core@<master-node>.<cluster_name>.<base_domain>
```

```
$ sudo systemctl reboot
```

6. After the reboot is complete, mark the node as schedulable by running the following command:



```
$ oc adm uncordon <node1>
```



## NOTE

With some single-node OpenShift clusters, the **oc** commands might not be available after you cordon and drain the node because the **openshift-oauth-apiserver** pod is not running. You can use SSH to connect to the node and uncordon it.

```
$ ssh core@<target_node>
```

```
$ sudo oc adm uncordon <node> --kubeconfig /etc/kubernetes/static-pod-resources/kube-apiserver-certs/secrets/node-kubeconfigs/localhost.kubeconfig
```

7. Verify that the node is ready:

```
$ oc get node <node1>
```

### Example output

```
NAME STATUS ROLES AGE VERSION
<node1> Ready worker 6d22h v1.18.3+b0068a8
```

### Additional information

For information on etcd data backup, see [Backing up etcd data](#).

## 6.9. FREEING NODE RESOURCES USING GARBAGE COLLECTION

As an administrator, you can use OpenShift Container Platform to ensure that your nodes are running efficiently by freeing up resources through garbage collection.

The OpenShift Container Platform node performs two types of garbage collection:

- Container garbage collection: Removes terminated containers.
- Image garbage collection: Removes images not referenced by any running pods.

### 6.9.1. Understanding how terminated containers are removed through garbage collection

Container garbage collection removes terminated containers by using eviction thresholds.

When eviction thresholds are set for garbage collection, the node tries to keep any container for any pod accessible from the API. If the pod has been deleted, the containers will be as well. Containers are preserved as long the pod is not deleted and the eviction threshold is not reached. If the node is under disk pressure, it will remove containers and their logs will no longer be accessible using **oc logs**.

- **eviction-soft** – A soft eviction threshold pairs an eviction threshold with a required administrator-specified grace period.

- **eviction-hard** - A hard eviction threshold has no grace period, and if observed, OpenShift Container Platform takes immediate action.

The following table lists the eviction thresholds:

**Table 6.5. Variables for configuring container garbage collection**

Node condition	Eviction signal	Description
MemoryPressure	<b>memory.available</b>	The available memory on the node.
DiskPressure	<ul style="list-style-type: none"> <li>• <b>nodefs.available</b></li> <li>• <b>nodefs.inodesFree</b></li> <li>• <b>imagefs.available</b></li> <li>• <b>imagefs.inodesFree</b></li> </ul>	The available disk space or inodes on the node root file system, <b>nodefs</b> , or image file system, <b>imagefs</b> .



#### NOTE

For **evictionHard** you must specify all of these parameters. If you do not specify all parameters, only the specified parameters are applied and the garbage collection will not function properly.

If a node is oscillating above and below a soft eviction threshold, but not exceeding its associated grace period, the corresponding node would constantly oscillate between **true** and **false**. As a consequence, the scheduler could make poor scheduling decisions.

To protect against this oscillation, use the **eviction-pressure-transition-period** flag to control how long OpenShift Container Platform must wait before transitioning out of a pressure condition. OpenShift Container Platform will not set an eviction threshold as being met for the specified pressure condition for the period specified before toggling the condition back to false.

### 6.9.2. Understanding how images are removed through garbage collection

Image garbage collection removes images that are not referenced by any running pods.

OpenShift Container Platform determines which images to remove from a node based on the disk usage that is reported by **cAdvisor**.

The policy for image garbage collection is based on two conditions:

- The percent of disk usage (expressed as an integer) which triggers image garbage collection. The default is **85**.
- The percent of disk usage (expressed as an integer) to which image garbage collection attempts to free. Default is **80**.

For image garbage collection, you can modify any of the following variables using a custom resource.

**Table 6.6. Variables for configuring image garbage collection**

Setting	Description
<b>imageMinimumGCAge</b>	The minimum age for an unused image before the image is removed by garbage collection. The default is <b>2m</b> .
<b>imageGCHighThresholdPercent</b>	The percent of disk usage, expressed as an integer, which triggers image garbage collection. The default is <b>85</b> .
<b>imageGCLowThresholdPercent</b>	The percent of disk usage, expressed as an integer, to which image garbage collection attempts to free. The default is <b>80</b> .

Two lists of images are retrieved in each garbage collector run:

1. A list of images currently running in at least one pod.
2. A list of images available on a host.

As new containers are run, new images appear. All images are marked with a time stamp. If the image is running (the first list above) or is newly detected (the second list above), it is marked with the current time. The remaining images are already marked from the previous spins. All images are then sorted by the time stamp.

Once the collection starts, the oldest images get deleted first until the stopping criterion is met.

### 6.9.3. Configuring garbage collection for containers and images

As an administrator, you can configure how OpenShift Container Platform performs garbage collection by creating a **kubeletConfig** object for each machine config pool.



#### NOTE

OpenShift Container Platform supports only one **kubeletConfig** object for each machine config pool.

You can configure any combination of the following:

- Soft eviction for containers
- Hard eviction for containers
- Eviction for images

Container garbage collection removes terminated containers. Image garbage collection removes images that are not referenced by any running pods.

#### Prerequisites

1. Obtain the label associated with the static **MachineConfigPool** CRD for the type of node you want to configure by entering the following command:

```
$ oc edit machineconfigpool <name>
```

For example:

```
$ oc edit machineconfigpool worker
```

### Example output

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfigPool
metadata:
  creationTimestamp: "2022-11-16T15:34:25Z"
  generation: 4
  labels:
    pools.operator.machineconfiguration.openshift.io/worker: "" 1
  name: worker
#...
```

**1** The label appears under Labels.

### TIP

If the label is not present, add a key/value pair such as:

```
$ oc label machineconfigpool worker custom-kubelet=small-pods
```

### Procedure

1. Create a custom resource (CR) for your configuration change.



### IMPORTANT

If there is one file system, or if `/var/lib/kubelet` and `/var/lib/containers/` are in the same file system, the settings with the highest values trigger evictions, as those are met first. The file system triggers the eviction.

### Sample configuration for a container garbage collection CR

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: worker-kubeconfig 1
spec:
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" 2
  kubeletConfig:
    evictionSoft: 3
      memory.available: "500Mi" 4
      nodefs.available: "10%"
      nodefs.inodesFree: "5%"
      imagefs.available: "15%"
      imagefs.inodesFree: "10%"
```

```

evictionSoftGracePeriod: 5
  memory.available: "1m30s"
  nodefs.available: "1m30s"
  nodefs.inodesFree: "1m30s"
  imagefs.available: "1m30s"
  imagefs.inodesFree: "1m30s"
evictionHard: 6
  memory.available: "200Mi"
  nodefs.available: "5%"
  nodefs.inodesFree: "4%"
  imagefs.available: "10%"
  imagefs.inodesFree: "5%"
evictionPressureTransitionPeriod: 0s 7
imageMinimumGCAge: 5m 8
imageGCHighThresholdPercent: 80 9
imageGCLowThresholdPercent: 75 10
#...

```

- 1 Name for the object.
- 2 Specify the label from the machine config pool.
- 3 For container garbage collection: Type of eviction: **evictionSoft** or **evictionHard**.
- 4 For container garbage collection: Eviction thresholds based on a specific eviction trigger signal.
- 5 For container garbage collection: Grace periods for the soft eviction. This parameter does not apply to **eviction-hard**.
- 6 For container garbage collection: Eviction thresholds based on a specific eviction trigger signal. For **evictionHard** you must specify all of these parameters. If you do not specify all parameters, only the specified parameters are applied and the garbage collection will not function properly.
- 7 For container garbage collection: The duration to wait before transitioning out of an eviction pressure condition.
- 8 For image garbage collection: The minimum age for an unused image before the image is removed by garbage collection.
- 9 For image garbage collection: The percent of disk usage (expressed as an integer) that triggers image garbage collection.
- 10 For image garbage collection: The percent of disk usage (expressed as an integer) that image garbage collection attempts to free.

2. Run the following command to create the CR:

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

For example:

```
$ oc create -f gc-container.yaml
```

## Example output

```
kubeletconfig.machineconfiguration.openshift.io/gc-container created
```

## Verification

1. Verify that garbage collection is active by entering the following command. The Machine Config Pool you specified in the custom resource appears with **UPDATING** as 'true` until the change is fully implemented:

```
$ oc get machineconfigpool
```

## Example output

```
NAME      CONFIG                                UPDATED  UPDATING
master    rendered-master-546383f80705bd5aeaba93  True     False
worker    rendered-worker-b4c51bb33ccae6fc4a6a5  False    True
```

## 6.10. ALLOCATING RESOURCES FOR NODES IN AN OPENSIFT CONTAINER PLATFORM CLUSTER

To provide more reliable scheduling and minimize node resource overcommitment, reserve a portion of the CPU and memory resources for use by the underlying node components, such as **kubelet** and **kube-proxy**, and the remaining system components, such as **sshd** and **NetworkManager**. By specifying the resources to reserve, you provide the scheduler with more information about the remaining CPU and memory resources that a node has available for use by pods. You can allow OpenShift Container Platform to [automatically determine the optimal system-reserved CPU and memory resources](#) for your nodes or you can [manually determine and set the best resources](#) for your nodes.



### IMPORTANT

To manually set resource values, you must use a kubelet config CR. You cannot use a machine config CR.

### 6.10.1. Understanding how to allocate resources for nodes

CPU and memory resources reserved for node components in OpenShift Container Platform are based on two node settings:

Setting	Description
<b>kube-reserved</b>	This setting is not used with OpenShift Container Platform. Add the CPU and memory resources that you planned to reserve to the <b>system-reserved</b> setting.
<b>system-reserved</b>	This setting identifies the resources to reserve for the node components and system components, such as CRI-O and Kubelet. The default settings depend on the OpenShift Container Platform and Machine Config Operator versions. Confirm the default <b>systemReserved</b> parameter on the <b>machine-config-operator</b> repository.

If a flag is not set, the defaults are used. If none of the flags are set, the allocated resource is set to the node's capacity as it was before the introduction of allocatable resources.



#### NOTE

Any CPUs specifically reserved using the **reservedSystemCPUs** parameter are not available for allocation using **kube-reserved** or **system-reserved**.

### 6.10.1.1. How OpenShift Container Platform computes allocated resources

An allocated amount of a resource is computed based on the following formula:

$$[\text{Allocatable}] = [\text{Node Capacity}] - [\text{system-reserved}] - [\text{Hard-Eviction-Thresholds}]$$



#### NOTE

The withholding of **Hard-Eviction-Thresholds** from **Allocatable** improves system reliability because the value for **Allocatable** is enforced for pods at the node level.

If **Allocatable** is negative, it is set to **0**.

Each node reports the system resources that are used by the container runtime and kubelet. To simplify configuring the **system-reserved** parameter, view the resource use for the node by using the node summary API. The node summary is available at **/api/v1/nodes/<node>/proxy/stats/summary**.

### 6.10.1.2. How nodes enforce resource constraints

The node is able to limit the total amount of resources that pods can consume based on the configured allocatable value. This feature significantly improves the reliability of the node by preventing pods from using CPU and memory resources that are needed by system services such as the container runtime and node agent. To improve node reliability, administrators should reserve resources based on a target for resource use.

The node enforces resource constraints by using a new cgroup hierarchy that enforces quality of service. All pods are launched in a dedicated cgroup hierarchy that is separate from system daemons.

Administrators should treat system daemons similar to pods that have a guaranteed quality of service. System daemons can burst within their bounding control groups and this behavior must be managed as part of cluster deployments. Reserve CPU and memory resources for system daemons by specifying the amount of CPU and memory resources in **system-reserved**.

Enforcing **system-reserved** limits can prevent critical system services from receiving CPU and memory resources. As a result, a critical system service can be ended by the out-of-memory killer. The recommendation is to enforce **system-reserved** only if you have profiled the nodes exhaustively to determine precise estimates and you are confident that critical system services can recover if any process in that group is ended by the out-of-memory killer.

### 6.10.1.3. Understanding Eviction Thresholds

If a node is under memory pressure, it can impact the entire node and all pods running on the node. For example, a system daemon that uses more than its reserved amount of memory can trigger an out-of-memory event. To avoid or reduce the probability of system out-of-memory events, the node provides out-of-resource handling.

You can reserve some memory using the **--eviction-hard** flag. The node attempts to evict pods whenever memory availability on the node drops below the absolute value or percentage. If system daemons do not exist on a node, pods are limited to the memory **capacity - eviction-hard**. For this reason, resources set aside as a buffer for eviction before reaching out of memory conditions are not available for pods.

The following is an example to illustrate the impact of node allocatable for memory:

- Node capacity is **32Gi**
- **--system-reserved** is **3Gi**
- **--eviction-hard** is set to **100Mi**.

For this node, the effective node allocatable value is **28.9Gi**. If the node and system components use all their reservation, the memory available for pods is **28.9Gi**, and kubelet evicts pods when it exceeds this threshold.

If you enforce node allocatable, **28.9Gi**, with top-level cgroups, then pods can never exceed **28.9Gi**. Evictions are not performed unless system daemons consume more than **3.1Gi** of memory.

If system daemons do not use up all their reservation, with the above example, pods would face memcg OOM kills from their bounding cgroup before node evictions kick in. To better enforce QoS under this situation, the node applies the hard eviction thresholds to the top-level cgroup for all pods to be **Node Allocatable + Eviction Hard Thresholds**.

If system daemons do not use up all their reservation, the node will evict pods whenever they consume more than **28.9Gi** of memory. If eviction does not occur in time, a pod will be OOM killed if pods consume **29Gi** of memory.

#### 6.10.1.4. How the scheduler determines resource availability

The scheduler uses the value of **node.Status.Allocatable** instead of **node.Status.Capacity** to decide if a node will become a candidate for pod scheduling.

By default, the node will report its machine capacity as fully schedulable by the cluster.

#### 6.10.2. Automatically allocating resources for nodes

OpenShift Container Platform can automatically determine the optimal **system-reserved** CPU and memory resources for nodes associated with a specific machine config pool and update the nodes with those values when the nodes start. By default, the **system-reserved** CPU is **500m** and **system-reserved** memory is **1Gi**.

To automatically determine and allocate the **system-reserved** resources on nodes, create a **KubeletConfig** custom resource (CR) to set the **autoSizingReserved: true** parameter. A script on each node calculates the optimal values for the respective reserved resources based on the installed CPU and memory capacity on each node. The script takes into account that increased capacity requires a corresponding increase in the reserved resources.

Automatically determining the optimal **system-reserved** settings ensures that your cluster is running efficiently and prevents node failure due to resource starvation of system components, such as CRI-O and kubelet, without your needing to manually calculate and update the values.

This feature is disabled by default.

Prerequisites



## Prerequisites

1. Obtain the label associated with the static **MachineConfigPool** object for the type of node you want to configure by entering the following command:

```
$ oc edit machineconfigpool <name>
```

For example:

```
$ oc edit machineconfigpool worker
```

## Example output

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfigPool
metadata:
  creationTimestamp: "2022-11-16T15:34:25Z"
  generation: 4
  labels:
    pools.operator.machineconfiguration.openshift.io/worker: "" 1
  name: worker
#...
```

- 1 The label appears under **Labels**.

## TIP

If an appropriate label is not present, add a key/value pair such as:

```
$ oc label machineconfigpool worker custom-kubelet=small-pods
```

## Procedure

1. Create a custom resource (CR) for your configuration change:

### Sample configuration for a resource allocation CR

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: dynamic-node 1
spec:
  autoSizingReserved: true 2
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" 3
#...
```

- 1 Assign a name to CR.
- 2 Add the **autoSizingReserved** parameter set to **true** to allow OpenShift Container Platform to automatically determine and allocate the **system-reserved** resources on the nodes associated with the specified label. To disable automatic allocation on those nodes

nodes associated with the specified label. To disable automatic allocation on those nodes, set this parameter to **false**.

- 3 Specify the label from the machine config pool that you configured in the "Prerequisites" section. You can choose any desired labels for the machine config pool, such as **custom-kubelet: small-pods**, or the default label, **pools.operator.machineconfiguration.openshift.io/worker: ""**.

The previous example enables automatic resource allocation on all worker nodes. OpenShift Container Platform drains the nodes, applies the kubelet config, and restarts the nodes.

2. Create the CR by entering the following command:

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

### Verification

1. Log in to a node you configured by entering the following command:

```
$ oc debug node/<node_name>
```

2. Set **/host** as the root directory within the debug shell:

```
# chroot /host
```

3. View the **/etc/node-sizing.env** file:

### Example output

```
SYSTEM_RESERVED_MEMORY=3Gi
SYSTEM_RESERVED_CPU=0.08
```

The kubelet uses the **system-reserved** values in the **/etc/node-sizing.env** file. In the previous example, the worker nodes are allocated **0.08** CPU and 3 Gi of memory. It can take several minutes for the optimal values to appear.

### 6.10.3. Manually allocating resources for nodes

OpenShift Container Platform supports the CPU and memory resource types for allocation. The **ephemeral-resource** resource type is also supported. For the **cpu** type, you specify the resource quantity in units of cores, such as **200m**, **0.5**, or **1**. For **memory** and **ephemeral-storage**, you specify the resource quantity in units of bytes, such as **200Ki**, **50Mi**, or **5Gi**. By default, the **system-reserved** CPU is **500m** and **system-reserved** memory is **1Gi**.

As an administrator, you can set these values by using a kubelet config custom resource (CR) through a set of **<resource\_type>=<resource\_quantity>** pairs (e.g., **cpu=200m,memory=512Mi**).



#### IMPORTANT

You must use a kubelet config CR to manually set resource values. You cannot use a machine config CR.

For details on the recommended **system-reserved** values, refer to the [recommended system-reserved values](#).

## Prerequisites

1. Obtain the label associated with the static **MachineConfigPool** CRD for the type of node you want to configure by entering the following command:

```
$ oc edit machineconfigpool <name>
```

For example:

```
$ oc edit machineconfigpool worker
```

## Example output

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfigPool
metadata:
  creationTimestamp: "2022-11-16T15:34:25Z"
  generation: 4
  labels:
    pools.operator.machineconfiguration.openshift.io/worker: "" 1
  name: worker
#...
```

- 1** The label appears under Labels.

## TIP

If the label is not present, add a key/value pair such as:

```
$ oc label machineconfigpool worker custom-kubelet=small-pods
```

## Procedure

1. Create a custom resource (CR) for your configuration change.

### Sample configuration for a resource allocation CR

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: set-allocatable 1
spec:
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" 2
  kubeletConfig:
    systemReserved: 3
```

```
cpu: 1000m
memory: 1Gi
#...
```

- 1 Assign a name to CR.
- 2 Specify the label from the machine config pool.
- 3 Specify the resources to reserve for the node components and system components.

2. Run the following command to create the CR:

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

## 6.11. ALLOCATING SPECIFIC CPUS FOR NODES IN A CLUSTER

When using the [static CPU Manager policy](#), you can reserve specific CPUs for use by specific nodes in your cluster. For example, on a system with 24 CPUs, you could reserve CPUs numbered 0 - 3 for the control plane allowing the compute nodes to use CPUs 4 - 23.

### 6.11.1. Reserving CPUs for nodes

To explicitly define a list of CPUs that are reserved for specific nodes, create a **KubeletConfig** custom resource (CR) to define the **reservedSystemCPUs** parameter. This list supersedes the CPUs that might be reserved using the **systemReserved** parameter.

#### Procedure

1. Obtain the label associated with the machine config pool (MCP) for the type of node you want to configure:

```
$ oc describe machineconfigpool <name>
```

For example:

```
$ oc describe machineconfigpool worker
```

#### Example output

```
Name:      worker
Namespace:
Labels:    machineconfiguration.openshift.io/mco-built-in=
           pools.operator.machineconfiguration.openshift.io/worker= 1
Annotations: <none>
API Version: machineconfiguration.openshift.io/v1
Kind:      MachineConfigPool
#...
```

- 1 Get the MCP label.

2. Create a YAML file for the **KubeletConfig** CR:

```

apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: set-reserved-cpus 1
spec:
  kubeletConfig:
    reservedSystemCPUs: "0,1,2,3" 2
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" 3
#...

```

- 1** Specify a name for the CR.
- 2** Specify the core IDs of the CPUs you want to reserve for the nodes associated with the MCP.
- 3** Specify the label from the MCP.

3. Create the CR object:

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

### Additional resources

- For more information on the **systemReserved** parameter, see [Allocating resources for nodes in an OpenShift Container Platform cluster](#).

## 6.12. ENABLING TLS SECURITY PROFILES FOR THE KUBELET

You can use a TLS (Transport Layer Security) security profile to define which TLS ciphers are required by the kubelet when it is acting as an HTTP server. The kubelet uses its HTTP/GRPC server to communicate with the Kubernetes API server, which sends commands to pods, gathers logs, and run exec commands on pods through the kubelet.

A TLS security profile defines the TLS ciphers that the Kubernetes API server must use when connecting with the kubelet to protect communication between the kubelet and the Kubernetes API server.



### NOTE



By default, when the kubelet acts as a client with the Kubernetes API server, it automatically negotiates the TLS parameters with the API server.

### 6.12.1. Understanding TLS security profiles

You can use a TLS (Transport Layer Security) security profile to define which TLS ciphers are required by various OpenShift Container Platform components. The OpenShift Container Platform TLS security profiles are based on [Mozilla recommended configurations](#).

You can specify one of the following TLS security profiles for each component:

**Table 6.7. TLS security profiles**

Profile	Description
<b>Old</b>	<p>This profile is intended for use with legacy clients or libraries. The profile is based on the <a href="#">Old backward compatibility</a> recommended configuration.</p> <p>The <b>Old</b> profile requires a minimum TLS version of 1.0.</p> <div style="display: flex; align-items: flex-start;">  <div> <p><b>NOTE</b></p> <p>For the Ingress Controller, the minimum TLS version is converted from 1.0 to 1.1.</p> </div> </div>
<b>Intermediate</b>	<p>This profile is the recommended configuration for the majority of clients. It is the default TLS security profile for the Ingress Controller, kubelet, and control plane. The profile is based on the <a href="#">Intermediate compatibility</a> recommended configuration.</p> <p>The <b>Intermediate</b> profile requires a minimum TLS version of 1.2.</p>
<b>Modern</b>	<p>This profile is intended for use with modern clients that have no need for backwards compatibility. This profile is based on the <a href="#">Modern compatibility</a> recommended configuration.</p> <p>The <b>Modern</b> profile requires a minimum TLS version of 1.3.</p>
<b>Custom</b>	<p>This profile allows you to define the TLS version and ciphers to use.</p> <div style="background-color: #fff9c4; padding: 10px; margin-top: 10px;"> <div style="display: flex; align-items: center;">  <div> <p><b>WARNING</b></p> <p>Use caution when using a <b>Custom</b> profile, because invalid configurations can cause problems.</p> </div> </div> </div>



#### NOTE

When using one of the predefined profile types, the effective profile configuration is subject to change between releases. For example, given a specification to use the Intermediate profile deployed on release X.Y.Z, an upgrade to release X.Y.Z+1 might cause a new profile configuration to be applied, resulting in a rollout.

### 6.12.2. Configuring the TLS security profile for the kubelet

To configure a TLS security profile for the kubelet when it is acting as an HTTP server, create a **KubeletConfig** custom resource (CR) to specify a predefined or custom TLS security profile for specific nodes. If a TLS security profile is not configured, the default TLS security profile is **Intermediate**.

**Sample KubeletConfig CR that configures the Old TLS security profile on worker nodes**

■

```

apiVersion: config.openshift.io/v1
kind: KubeletConfig
...
spec:
  tlsSecurityProfile:
    old: {}
    type: Old
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: ""
#...

```

You can see the ciphers and the minimum TLS version of the configured TLS security profile in the **kubelet.conf** file on a configured node.

## Prerequisites

- You are logged in to OpenShift Container Platform as a user with the **cluster-admin** role.

## Procedure

1. Create a **KubeletConfig** CR to configure the TLS security profile:

### Sample KubeletConfig CR for a Custom profile

```

apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: set-kubelet-tls-security-profile
spec:
  tlsSecurityProfile:
    type: Custom 1
    custom: 2
      ciphers: 3
      - ECDHE-ECDSA-CHACHA20-POLY1305
      - ECDHE-RSA-CHACHA20-POLY1305
      - ECDHE-RSA-AES128-GCM-SHA256
      - ECDHE-ECDSA-AES128-GCM-SHA256
      minTLSVersion: VersionTLS11
    machineConfigPoolSelector:
      matchLabels:
        pools.operator.machineconfiguration.openshift.io/worker: "" 4
#...

```

- 1** Specify the TLS security profile type (**Old**, **Intermediate**, or **Custom**). The default is **Intermediate**.
- 2** Specify the appropriate field for the selected type:
  - **old:** {}
  - **intermediate:** {}
  - **custom:**

- 3 For the **custom** type, specify a list of TLS ciphers and minimum accepted TLS version.
- 4 Optional: Specify the machine config pool label for the nodes you want to apply the TLS security profile.

2. Create the **KubeletConfig** object:

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

Depending on the number of worker nodes in the cluster, wait for the configured nodes to be rebooted one by one.

## Verification

To verify that the profile is set, perform the following steps after the nodes are in the **Ready** state:

1. Start a debug session for a configured node:

```
$ oc debug node/<node_name>
```

2. Set **/host** as the root directory within the debug shell:

```
sh-4.4# chroot /host
```

3. View the **kubelet.conf** file:

```
sh-4.4# cat /etc/kubernetes/kubelet.conf
```

## Example output

```
"kind": "KubeletConfiguration",
"apiVersion": "kubelet.config.k8s.io/v1beta1",
#...
"tlsCipherSuites": [
  "TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256",
  "TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256",
  "TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384",
  "TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384",
  "TLS_ECDHE_ECDSA_WITH_CHACHA20_POLY1305_SHA256",
  "TLS_ECDHE_RSA_WITH_CHACHA20_POLY1305_SHA256"
],
"tlsMinVersion": "VersionTLS12",
#...
```

## 6.13. CREATING INFRASTRUCTURE NODES





## IMPORTANT

You can use the advanced machine management and scaling capabilities only in clusters where the Machine API is operational. Clusters with user-provisioned infrastructure require additional validation and configuration to use the Machine API.

Clusters with the infrastructure platform type **none** cannot use the Machine API. This limitation applies even if the compute machines that are attached to the cluster are installed on a platform that supports the feature. This parameter cannot be changed after installation.

To view the platform type for your cluster, run the following command:

```
$ oc get infrastructure cluster -o jsonpath='{.status.platform}'
```

You can use infrastructure machine sets to create machines that host only infrastructure components, such as the default router, the integrated container image registry, and the components for cluster metrics and monitoring. These infrastructure machines are not counted toward the total number of subscriptions that are required to run the environment.

In a production deployment, it is recommended that you deploy at least three machine sets to hold infrastructure components. Both OpenShift Logging and Red Hat OpenShift Service Mesh deploy Elasticsearch, which requires three instances to be installed on different nodes. Each of these nodes can be deployed to different availability zones for high availability. This configuration requires three different machine sets, one for each availability zone. In global Azure regions that do not have multiple availability zones, you can use availability sets to ensure high availability.



## NOTE

After adding the **NoSchedule** taint on the infrastructure node, existing DNS pods running on that node are marked as **misscheduled**. You must either delete or [add toleration on misscheduled DNS pods](#).

### 6.13.1. OpenShift Container Platform infrastructure components

Each self-managed Red Hat OpenShift subscription includes entitlements for OpenShift Container Platform and other OpenShift-related components. These entitlements are included for running OpenShift Container Platform control plane and infrastructure workloads and do not need to be accounted for during sizing.

To qualify as an infrastructure node and use the included entitlement, only components that are supporting the cluster, and not part of an end-user application, can run on those instances. Examples include the following components:

- Kubernetes and OpenShift Container Platform control plane services
- The default router
- The integrated container image registry
- The HAProxy-based Ingress Controller
- The cluster metrics collection, or monitoring service, including components for monitoring user-defined projects

- Cluster aggregated logging
- Red Hat Quay
- Red Hat OpenShift Data Foundation
- Red Hat Advanced Cluster Management for Kubernetes
- Red Hat Advanced Cluster Security for Kubernetes
- Red Hat OpenShift GitOps
- Red Hat OpenShift Pipelines
- Red Hat OpenShift Service Mesh

Any node that runs any other container, pod, or component is a worker node that your subscription must cover.

For information about infrastructure nodes and which components can run on infrastructure nodes, see the "Red Hat OpenShift control plane and infrastructure nodes" section in the [OpenShift sizing and subscription guide for enterprise Kubernetes](#) document.

To create an infrastructure node, you can [use a machine set](#), [label the node](#), or [use a machine config pool](#).

### 6.13.1.1. Creating an infrastructure node



#### IMPORTANT

See [Creating infrastructure machine sets for installer-provisioned infrastructure environments](#) or for any cluster where the control plane nodes are managed by the machine API.

Requirements of the cluster dictate that infrastructure, also called **infra** nodes, be provisioned. The installer only provides provisions for control plane and worker nodes. Worker nodes can be designated as infrastructure nodes or application, also called **app**, nodes through labeling.

#### Procedure

1. Add a label to the worker node that you want to act as application node:

```
$ oc label node <node-name> node-role.kubernetes.io/app=""
```

2. Add a label to the worker nodes that you want to act as infrastructure nodes:

```
$ oc label node <node-name> node-role.kubernetes.io/infra=""
```

3. Check to see if applicable nodes now have the **infra** role and **app** roles:

```
$ oc get nodes
```

4. Create a default cluster-wide node selector. The default node selector is applied to pods created in all namespaces. This creates an intersection with any existing node selectors on a pod, which additionally constrains the pod's selector.



### IMPORTANT

If the default node selector key conflicts with the key of a pod's label, then the default node selector is not applied.

However, do not set a default node selector that might cause a pod to become unschedulable. For example, setting the default node selector to a specific node role, such as `node-role.kubernetes.io/infra=""`, when a pod's label is set to a different node role, such as `node-role.kubernetes.io/master=""`, can cause the pod to become unschedulable. For this reason, use caution when setting the default node selector to specific node roles.

You can alternatively use a project node selector to avoid cluster-wide node selector key conflicts.

- a. Edit the **Scheduler** object:

```
$ oc edit scheduler cluster
```

- b. Add the **defaultNodeSelector** field with the appropriate node selector:

```
apiVersion: config.openshift.io/v1
kind: Scheduler
metadata:
  name: cluster
spec:
  defaultNodeSelector: node-role.kubernetes.io/infra="" 1
# ...
```

- 1 This example node selector deploys pods on infrastructure nodes by default.

- c. Save the file to apply the changes.

You can now move infrastructure resources to the newly labeled **infra** nodes.

### Additional resources

- [Moving resources to infrastructure machine sets](#)

## CHAPTER 7. WORKING WITH CONTAINERS

### 7.1. UNDERSTANDING CONTAINERS

The basic units of OpenShift Container Platform applications are called *containers*. [Linux container technologies](#) are lightweight mechanisms for isolating running processes so that they are limited to interacting with only their designated resources.

Many application instances can be running in containers on a single host without visibility into each others' processes, files, network, and so on. Typically, each container provides a single service (often called a "micro-service"), such as a web server or a database, though containers can be used for arbitrary workloads.

The Linux kernel has been incorporating capabilities for container technologies for years. OpenShift Container Platform and Kubernetes add the ability to orchestrate containers across multi-host installations.

#### 7.1.1. About containers and RHEL kernel memory

Due to Red Hat Enterprise Linux (RHEL) behavior, a container on a node with high CPU usage might seem to consume more memory than expected. The higher memory consumption could be caused by the **kmem\_cache** in the RHEL kernel. The RHEL kernel creates a **kmem\_cache** for each cgroup. For added performance, the **kmem\_cache** contains a **cpu\_cache**, and a node cache for any NUMA nodes. These caches all consume kernel memory.

The amount of memory stored in those caches is proportional to the number of CPUs that the system uses. As a result, a higher number of CPUs results in a greater amount of kernel memory being held in these caches. Higher amounts of kernel memory in these caches can cause OpenShift Container Platform containers to exceed the configured memory limits, resulting in the container being killed.

To avoid losing containers due to kernel memory issues, ensure that the containers request sufficient memory. You can use the following formula to estimate the amount of memory consumed by the **kmem\_cache**, where **nproc** is the number of processing units available that are reported by the **nproc** command. The lower limit of container requests should be this value plus the container memory requirements:

$$\$(nproc) \times 1/2 \text{ MiB}$$

#### 7.1.2. About the container engine and container runtime

A *container engine* is a piece of software that processes user requests, including command line options and image pulls. The container engine uses a *container runtime*, also called a *lower-level container runtime*, to run and manage the components required to deploy and operate containers. You likely will not need to interact with the container engine or container runtime.



#### NOTE

The OpenShift Container Platform documentation uses the term *container runtime* to refer to the lower-level container runtime. Other documentation can refer to the container engine as the container runtime.

OpenShift Container Platform uses CRI-O as the container engine and runC or crun as the container runtime. The default container runtime is runC. Both container runtimes adhere to the [Open Container Initiative \(OCI\)](#) runtime specifications.

CRI-O is a Kubernetes-native container engine implementation that integrates closely with the operating system to deliver an efficient and optimized Kubernetes experience. The CRI-O container engine runs as a systemd service on each OpenShift Container Platform cluster node.

runC, developed by Docker and maintained by the Open Container Project, is a lightweight, portable container runtime written in Go. crun, developed by Red Hat, is a fast and low-memory container runtime fully written in C. As of OpenShift Container Platform 4.17, you can select between the two.

crun has several improvements over runC, including:

- Smaller binary
- Quicker processing
- Lower memory footprint

runC has some benefits over crun, including:

- Most popular OCI container runtime.
- Longer tenure in production.
- Default container runtime of CRI-O.

You can move between the two container runtimes as needed.

For information on setting which container runtime to use, see [Creating a ContainerRuntimeConfig CR to edit CRI-O parameters](#).

## 7.2. USING INIT CONTAINERS TO PERFORM TASKS BEFORE A POD IS DEPLOYED

OpenShift Container Platform provides *init containers*, which are specialized containers that run before application containers and can contain utilities or setup scripts not present in an app image.

### 7.2.1. Understanding Init Containers

You can use an Init Container resource to perform tasks before the rest of a pod is deployed.

A pod can have Init Containers in addition to application containers. Init containers allow you to reorganize setup scripts and binding code.

An Init Container can:

- Contain and run utilities that are not desirable to include in the app Container image for security reasons.
- Contain utilities or custom code for setup that is not present in an app image. For example, there is no requirement to make an image FROM another image just to use a tool like sed, awk, python, or dig during setup.

- Use Linux namespaces so that they have different filesystem views from app containers, such as access to secrets that application containers are not able to access.

Each Init Container must complete successfully before the next one is started. So, Init Containers provide an easy way to block or delay the startup of app containers until some set of preconditions are met.

For example, the following are some ways you can use Init Containers:

- Wait for a service to be created with a shell command like:

```
for i in {1..100}; do sleep 1; if dig myservice; then exit 0; fi; done; exit 1
```

- Register this pod with a remote server from the downward API with a command like:

```
$ curl -X POST
http://$MANAGEMENT_SERVICE_HOST:$MANAGEMENT_SERVICE_PORT/register -d
'instance=${}&ip=${}'
```

- Wait for some time before starting the app Container with a command like **sleep 60**.
- Clone a git repository into a volume.
- Place values into a configuration file and run a template tool to dynamically generate a configuration file for the main app Container. For example, place the `POD_IP` value in a configuration and generate the main app configuration file using Jinja.

See the [Kubernetes documentation](#) for more information.

## 7.2.2. Creating Init Containers

The following example outlines a simple pod which has two Init Containers. The first waits for **myservice** and the second waits for **mydb**. After both containers complete, the pod begins.

### Procedure

1. Create the pod for the Init Container:
  - a. Create a YAML file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: myapp-pod
  labels:
    app: myapp
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - name: myapp-container
    image: registry.access.redhat.com/ubi9/ubi:latest
    command: ['sh', '-c', 'echo The app is running! && sleep 3600']
```

```

securityContext:
  allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]
initContainers:
- name: init-myservice
  image: registry.access.redhat.com/ubi9/ubi:latest
  command: ['sh', '-c', 'until getent hosts myservice; do echo waiting for myservice; sleep
2; done;']
securityContext:
  allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]
- name: init-mydb
  image: registry.access.redhat.com/ubi9/ubi:latest
  command: ['sh', '-c', 'until getent hosts mydb; do echo waiting for mydb; sleep 2;
done;']
securityContext:
  allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]

```

- b. Create the pod:

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

- c. View the status of the pod:

```
$ oc get pods
```

### Example output

```

NAME                READY   STATUS    RESTARTS   AGE
myapp-pod           0/1    Init:0/2    0          5s

```

The pod status, **Init:0/2**, indicates it is waiting for the two services.

2. Create the **myservice** service.

- a. Create a YAML file similar to the following:

```

kind: Service
apiVersion: v1
metadata:
  name: myservice
spec:
  ports:
  - protocol: TCP
    port: 80
    targetPort: 9376

```

- b. Create the pod:

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

- c. View the status of the pod:

```
$ oc get pods
```

#### Example output

NAME	READY	STATUS	RESTARTS	AGE
myapp-pod	0/1	Init:1/2	0	5s

The pod status, **Init:1/2**, indicates it is waiting for one service, in this case the **mydb** service.

3. Create the **mydb** service:

- a. Create a YAML file similar to the following:

```
kind: Service
apiVersion: v1
metadata:
  name: mydb
spec:
  ports:
  - protocol: TCP
    port: 80
    targetPort: 9377
```

- b. Create the pod:

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

- c. View the status of the pod:

```
$ oc get pods
```

#### Example output

NAME	READY	STATUS	RESTARTS	AGE
myapp-pod	1/1	Running	0	2m

The pod status indicated that it is no longer waiting for the services and is running.

## 7.3. USING VOLUMES TO PERSIST CONTAINER DATA

Files in a container are ephemeral. As such, when a container crashes or stops, the data is lost. You can use *volumes* to persist the data used by the containers in a pod. A volume is directory, accessible to the Containers in a pod, where data is stored for the life of the pod.

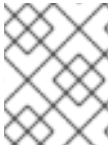
### 7.3.1. Understanding volumes

Volumes are mounted file systems available to pods and their containers which may be backed by a number of host-local or network attached storage endpoints. Containers are not persistent by default; on restart, their contents are cleared.



To ensure that the file system on the volume contains no errors and, if errors are present, to repair them when possible, OpenShift Container Platform invokes the **fsck** utility prior to the **mount** utility. This occurs when either adding a volume or updating an existing volume.

The simplest volume type is **emptyDir**, which is a temporary directory on a single machine. Administrators may also allow you to request a persistent volume that is automatically attached to your pods.



#### NOTE

**emptyDir** volume storage may be restricted by a quota based on the pod's FSGroup, if the FSGroup parameter is enabled by your cluster administrator.

### 7.3.2. Working with volumes using the OpenShift Container Platform CLI

You can use the CLI command **oc set volume** to add and remove volumes and volume mounts for any object that has a pod template like replication controllers or deployment configs. You can also list volumes in pods or any object that has a pod template.

The **oc set volume** command uses the following general syntax:

```
$ oc set volume <object_selection> <operation> <mandatory_parameters> <options>
```

#### Object selection

Specify one of the following for the **object\_selection** parameter in the **oc set volume** command:

Table 7.1. Object Selection

Syntax	Description	Example
<b>&lt;object_type&gt; &lt;name&gt;</b>	Selects <b>&lt;name&gt;</b> of type <b>&lt;object_type&gt;</b> .	<b>deploymentConfig registry</b>
<b>&lt;object_type&gt;/&lt;name&gt;</b>	Selects <b>&lt;name&gt;</b> of type <b>&lt;object_type&gt;</b> .	<b>deploymentConfig/registry</b>
<b>&lt;object_type&gt;--selector=&lt;object_label_selector&gt;</b>	Selects resources of type <b>&lt;object_type&gt;</b> that matched the given label selector.	<b>deploymentConfig--selector="name=registry"</b>
<b>&lt;object_type&gt; --all</b>	Selects all resources of type <b>&lt;object_type&gt;</b> .	<b>deploymentConfig --all</b>
<b>-f or --filename=&lt;file_name&gt;</b>	File name, directory, or URL to file to use to edit the resource.	<b>-f registry-deployment-config.json</b>

#### Operation

Specify **--add** or **--remove** for the **operation** parameter in the **oc set volume** command.

#### Mandatory parameters

Any mandatory parameters are specific to the selected operation and are discussed in later sections.

#### Options

Any options are specific to the selected operation and are discussed in later sections.

### 7.3.3. Listing volumes and volume mounts in a pod

You can list volumes and volume mounts in pods or pod templates:

#### Procedure

To list volumes:

```
$ oc set volume <object_type>/<name> [options]
```

List volume supported options:

Option	Description	Default
<b>--name</b>	Name of the volume.	
<b>-c, --containers</b>	Select containers by name. It can also take wildcard <b>'*'</b> that matches any character.	<b>'*'</b>

For example:

- To list all volumes for pod **p1**:

```
$ oc set volume pod/p1
```

- To list volume **v1** defined on all deployment configs:

```
$ oc set volume dc --all --name=v1
```

### 7.3.4. Adding volumes to a pod

You can add volumes and volume mounts to a pod.

#### Procedure

To add a volume, a volume mount, or both to pod templates:

```
$ oc set volume <object_type>/<name> --add [options]
```

Table 7.2. Supported Options for Adding Volumes

Option	Description	Default
<b>--name</b>	Name of the volume.	Automatically generated, if not specified.

Option	Description	Default
<b>-t, --type</b>	Name of the volume source. Supported values: <b>emptyDir</b> , <b>hostPath</b> , <b>secret</b> , <b>configmap</b> , <b>persistentVolumeClaim</b> or <b>projected</b> .	<b>emptyDir</b>
<b>-c, --containers</b>	Select containers by name. It can also take wildcard <b>'*'</b> that matches any character.	<b>'*'</b>
<b>-m, --mount-path</b>	Mount path inside the selected containers. Do not mount to the container root, <b>/</b> , 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 <b>/dev/pts</b> files. It is safe to mount the host by using <b>/host</b> .	
<b>--path</b>	Host path. Mandatory parameter for <b>--type=hostPath</b> . Do not mount to the container root, <b>/</b> , 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 <b>/dev/pts</b> files. It is safe to mount the host by using <b>/host</b> .	
<b>--secret-name</b>	Name of the secret. Mandatory parameter for <b>--type=secret</b> .	
<b>--configmap-name</b>	Name of the configmap. Mandatory parameter for <b>--type=configmap</b> .	
<b>--claim-name</b>	Name of the persistent volume claim. Mandatory parameter for <b>--type=persistentVolumeClaim</b> .	
<b>--source</b>	Details of volume source as a JSON string. Recommended if the desired volume source is not supported by <b>--type</b> .	

Option	Description	Default
<b>-o, --output</b>	Display the modified objects instead of updating them on the server. Supported values: <b>json</b> , <b>yaml</b> .	
<b>--output-version</b>	Output the modified objects with the given version.	<b>api-version</b>

For example:

- To add a new volume source **emptyDir** to the **registry DeploymentConfig** object:

```
$ oc set volume dc/registry --add
```

### TIP

You can alternatively apply the following YAML to add the volume:

#### Example 7.1. Sample deployment config with an added volume

```
kind: DeploymentConfig
apiVersion: apps.openshift.io/v1
metadata:
  name: registry
  namespace: registry
spec:
  replicas: 3
  selector:
    app: httpd
  template:
    metadata:
      labels:
        app: httpd
    spec:
      volumes: 1
      - name: volume-pppsw
        emptyDir: {}
    containers:
      - name: httpd
        image: >-
          image-registry.openshift-image-registry.svc:5000/openshift/httpd:latest
        ports:
          - containerPort: 8080
            protocol: TCP
```

- 1 Add the volume source **emptyDir**.

- To add volume **v1** with secret **secret1** for replication controller **r1** and mount inside the containers at **/data**:

```
$ oc set volume rc/r1 --add --name=v1 --type=secret --secret-name='secret1' --mount-path=/data
```

## TIP

You can alternatively apply the following YAML to add the volume:

### Example 7.2. Sample replication controller with added volume and secret

```
kind: ReplicationController
apiVersion: v1
metadata:
  name: example-1
  namespace: example
spec:
  replicas: 0
  selector:
    app: httpd
    deployment: example-1
    deploymentconfig: example
  template:
    metadata:
      creationTimestamp: null
    labels:
      app: httpd
      deployment: example-1
      deploymentconfig: example
    spec:
      volumes: ①
      - name: v1
        secret:
          secretName: secret1
          defaultMode: 420
      containers:
      - name: httpd
        image: >-
          image-registry.openshift-image-registry.svc:5000/openshift/httpd:latest
        volumeMounts: ②
        - name: v1
          mountPath: /data
```

- ① Add the volume and secret.
- ② Add the container mount path.

- To add existing persistent volume **v1** with claim name **pvc1** to deployment configuration **dc.json** on disk, mount the volume on container **c1** at **/data**, and update the **DeploymentConfig** object on the server:

```
$ oc set volume -f dc.json --add --name=v1 --type=persistentVolumeClaim \
--claim-name=pvc1 --mount-path=/data --containers=c1
```

## TIP

You can alternatively apply the following YAML to add the volume:

### Example 7.3. Sample deployment config with persistent volume added

```
kind: DeploymentConfig
apiVersion: apps.openshift.io/v1
metadata:
  name: example
  namespace: example
spec:
  replicas: 3
  selector:
    app: httpd
  template:
    metadata:
      labels:
        app: httpd
    spec:
      volumes:
        - name: volume-pppsw
          emptyDir: {}
        - name: v1 1
          persistentVolumeClaim:
            claimName: pvc1
      containers:
        - name: httpd
          image: >-
            image-registry.openshift-image-registry.svc:5000/openshift/httpd:latest
          ports:
            - containerPort: 8080
              protocol: TCP
          volumeMounts: 2
            - name: v1
              mountPath: /data
```

**1** Add the persistent volume claim named `pvc1`.

**2** Add the container mount path.

- To add a volume `v1` based on Git repository <https://github.com/namespace1/project1> with revision `5125c45f9f563` for all replication controllers:

```
$ oc set volume rc --all --add --name=v1 \
  --source='{ "gitRepo": {
    "repository": "https://github.com/namespace1/project1",
    "revision": "5125c45f9f563"
  } }'
```

### 7.3.5. Updating volumes and volume mounts in a pod

You can modify the volumes and volume mounts in a pod.

## Procedure

Updating existing volumes using the **--overwrite** option:

```
$ oc set volume <object_type>/<name> --add --overwrite [options]
```

For example:

- To replace existing volume **v1** for replication controller **r1** with existing persistent volume claim **pvc1**:

```
$ oc set volume rc/r1 --add --overwrite --name=v1 --type=persistentVolumeClaim --claim-name=pvc1
```

**TIP**

You can alternatively apply the following YAML to replace the volume:

**Example 7.4. Sample replication controller with persistent volume claim named `pvc1`**

```
kind: ReplicationController
apiVersion: v1
metadata:
  name: example-1
  namespace: example
spec:
  replicas: 0
  selector:
    app: httpd
    deployment: example-1
    deploymentconfig: example
  template:
    metadata:
      labels:
        app: httpd
        deployment: example-1
        deploymentconfig: example
    spec:
      volumes:
        - name: v1 1
          persistentVolumeClaim:
            claimName: pvc1
      containers:
        - name: httpd
          image: >-
            image-registry.openshift-image-registry.svc:5000/openshift/httpd:latest
          ports:
            - containerPort: 8080
              protocol: TCP
          volumeMounts:
            - name: v1
              mountPath: /data
```

**1** Set persistent volume claim to **`pvc1`**.

- To change the **DeploymentConfig** object **`d1`** mount point to **`/opt`** for volume **`v1`**:

```
$ oc set volume dc/d1 --add --overwrite --name=v1 --mount-path=/opt
```



**TIP**

You can alternatively apply the following YAML to change the mount point:

**Example 7.5. Sample deployment config with mount point set to `opt`.**

```
kind: DeploymentConfig
apiVersion: apps.openshift.io/v1
metadata:
  name: example
  namespace: example
spec:
  replicas: 3
  selector:
    app: httpd
  template:
    metadata:
      labels:
        app: httpd
    spec:
      volumes:
        - name: volume-pppsw
          emptyDir: {}
        - name: v2
          persistentVolumeClaim:
            claimName: pvc1
        - name: v1
          persistentVolumeClaim:
            claimName: pvc1
      containers:
        - name: httpd
          image: >-
            image-registry.openshift-image-registry.svc:5000/openshift/httpd:latest
          ports:
            - containerPort: 8080
              protocol: TCP
          volumeMounts: ❶
            - name: v1
              mountPath: /opt
```

❶ Set the mount point to `/opt`.

**7.3.6. Removing volumes and volume mounts from a pod**

You can remove a volume or volume mount from a pod.

**Procedure**

To remove a volume from pod templates:

```
$ oc set volume <object_type>/<name> --remove [options]
```

**Table 7.3. Supported options for removing volumes**

Option	Description	Default
<b>--name</b>	Name of the volume.	
<b>-c, --containers</b>	Select containers by name. It can also take wildcard <b>'**'</b> that matches any character.	<b>'**'</b>
<b>--confirm</b>	Indicate that you want to remove multiple volumes at once.	
<b>-o, --output</b>	Display the modified objects instead of updating them on the server. Supported values: <b>json</b> , <b>yaml</b> .	
<b>--output-version</b>	Output the modified objects with the given version.	<b>api-version</b>

For example:

- To remove a volume **v1** from the **DeploymentConfig** object **d1**:

```
$ oc set volume dc/d1 --remove --name=v1
```

- To unmount volume **v1** from container **c1** for the **DeploymentConfig** object **d1** and remove the volume **v1** if it is not referenced by any containers on **d1**:

```
$ oc set volume dc/d1 --remove --name=v1 --containers=c1
```

- To remove all volumes for replication controller **r1**:

```
$ oc set volume rc/r1 --remove --confirm
```

### 7.3.7. Configuring volumes for multiple uses in a pod

You can configure a volume to allow you to share one volume for multiple uses in a single pod using the **volumeMounts.subPath** property to specify a **subPath** value inside a volume instead of the volume's root.



#### NOTE

You cannot add a **subPath** parameter to an existing scheduled pod.

#### Procedure

1. To view the list of files in the volume, run the **oc rsh** command:

```
$ oc rsh <pod>
```

## Example output

```
sh-4.2$ ls /path/to/volume/subpath/mount
example_file1 example_file2 example_file3
```

- Specify the **subPath**:

## Example Pod spec with subPath parameter

```
apiVersion: v1
kind: Pod
metadata:
  name: my-site
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
    - name: mysql
      image: mysql
      volumeMounts:
        - mountPath: /var/lib/mysql
          name: site-data
          subPath: mysql 1
      securityContext:
        allowPrivilegeEscalation: false
        capabilities:
          drop: [ALL]
    - name: php
      image: php
      volumeMounts:
        - mountPath: /var/www/html
          name: site-data
          subPath: html 2
      securityContext:
        allowPrivilegeEscalation: false
        capabilities:
          drop: [ALL]
  volumes:
    - name: site-data
      persistentVolumeClaim:
        claimName: my-site-data
```

**1** Databases are stored in the **mysql** folder.

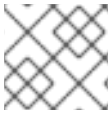
**2** HTML content is stored in the **html** folder.

## 7.4. MAPPING VOLUMES USING PROJECTED VOLUMES

A *projected volume* maps several existing volume sources into the same directory.

The following types of volume sources can be projected:

- Secrets
- Config Maps
- Downward API



#### NOTE

All sources are required to be in the same namespace as the pod.

### 7.4.1. Understanding projected volumes

Projected volumes can map any combination of these volume sources into a single directory, allowing the user to:

- automatically populate a single volume with the keys from multiple secrets, config maps, and with downward API information, so that I can synthesize a single directory with various sources of information;
- populate a single volume with the keys from multiple secrets, config maps, and with downward API information, explicitly specifying paths for each item, so that I can have full control over the contents of that volume.



#### IMPORTANT

When the **RunAsUser** permission is set in the security context of a Linux-based pod, the projected files have the correct permissions set, including container user ownership. However, when the Windows equivalent **RunAsUsername** permission is set in a Windows pod, the kubelet is unable to correctly set ownership on the files in the projected volume.

Therefore, the **RunAsUsername** permission set in the security context of a Windows pod is not honored for Windows projected volumes running in OpenShift Container Platform.

The following general scenarios show how you can use projected volumes.

#### Config map, secrets, Downward API.

Projected volumes allow you to deploy containers with configuration data that includes passwords. An application using these resources could be deploying Red Hat OpenStack Platform (RHOSP) on Kubernetes. The configuration data might have to be assembled differently depending on if the services are going to be used for production or for testing. If a pod is labeled with production or testing, the downward API selector **metadata.labels** can be used to produce the correct RHOSP configs.

#### Config map + secrets.

Projected volumes allow you to deploy containers involving configuration data and passwords. For example, you might execute a config map with some sensitive encrypted tasks that are decrypted using a vault password file.

#### ConfigMap + Downward API.

Projected volumes allow you to generate a config including the pod name (available via the **metadata.name** selector). This application can then pass the pod name along with requests to easily determine the source without using IP tracking.

#### Secrets + Downward API.

Projected volumes allow you to use a secret as a public key to encrypt the namespace of the pod (available via the **metadata.namespace** selector). This example allows the Operator to use the application to deliver the namespace information securely without using an encrypted transport.

### 7.4.1.1. Example Pod specs

The following are examples of **Pod** specs for creating projected volumes.

#### Pod with a secret, a Downward API, and a config map

```

apiVersion: v1
kind: Pod
metadata:
  name: volume-test
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: container-test
    image: busybox
    volumeMounts: 1
    - name: all-in-one
      mountPath: "/projected-volume" 2
      readOnly: true 3
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
  volumes: 4
  - name: all-in-one 5
    projected:
      defaultMode: 0400 6
      sources:
      - secret:
          name: mysecret 7
          items:
          - key: username
            path: my-group/my-username 8
      - downwardAPI: 9
          items:
          - path: "labels"
            fieldRef:
              fieldPath: metadata.labels
          - path: "cpu_limit"
            resourceFieldRef:
              containerName: container-test
              resource: limits.cpu
      - configMap: 10
          name: myconfigmap
          items:
  
```

```
- key: config
  path: my-group/my-config
  mode: 0777 11
```

- 1 Add a **volumeMounts** section for each container that needs the secret.
- 2 Specify a path to an unused directory where the secret will appear.
- 3 Set **readOnly** to **true**.
- 4 Add a **volumes** block to list each projected volume source.
- 5 Specify any name for the volume.
- 6 Set the execute permission on the files.
- 7 Add a secret. Enter the name of the secret object. Each secret you want to use must be listed.
- 8 Specify the path to the secrets file under the **mountPath**. Here, the secrets file is in */projected-volume/my-group/my-username*.
- 9 Add a Downward API source.
- 10 Add a ConfigMap source.
- 11 Set the mode for the specific projection



## NOTE

If there are multiple containers in the pod, each container needs a **volumeMounts** section, but only one **volumes** section is needed.

## Pod with multiple secrets with a non-default permission mode set

```
apiVersion: v1
kind: Pod
metadata:
  name: volume-test
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
    - name: container-test
      image: busybox
      volumeMounts:
        - name: all-in-one
          mountPath: "/projected-volume"
          readOnly: true
      securityContext:
        allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
```

```
volumes:
- name: all-in-one
  projected:
    defaultMode: 0755
    sources:
    - secret:
        name: mysecret
        items:
        - key: username
          path: my-group/my-username
    - secret:
        name: mysecret2
        items:
        - key: password
          path: my-group/my-password
          mode: 511
```



## NOTE

The **defaultMode** can only be specified at the projected level and not for each volume source. However, as illustrated above, you can explicitly set the **mode** for each individual projection.

### 7.4.1.2. Pathing Considerations

#### Collisions Between Keys when Configured Paths are Identical

If you configure any keys with the same path, the pod spec will not be accepted as valid. In the following example, the specified path for **mysecret** and **myconfigmap** are the same:

```
apiVersion: v1
kind: Pod
metadata:
  name: volume-test
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: container-test
    image: busybox
    volumeMounts:
    - name: all-in-one
      mountPath: "/projected-volume"
      readOnly: true
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
  volumes:
  - name: all-in-one
    projected:
      sources:
      - secret:
          name: mysecret
```

```

items:
  - key: username
    path: my-group/data
- configMap:
  name: myconfigmap
  items:
    - key: config
      path: my-group/data

```

Consider the following situations related to the volume file paths.

### Collisions Between Keys without Configured Paths

The only run-time validation that can occur is when all the paths are known at pod creation, similar to the above scenario. Otherwise, when a conflict occurs the most recent specified resource will overwrite anything preceding it (this is true for resources that are updated after pod creation as well).

### Collisions when One Path is Explicit and the Other is Automatically Projected

In the event that there is a collision due to a user specified path matching data that is automatically projected, the latter resource will overwrite anything preceding it as before

## 7.4.2. Configuring a Projected Volume for a Pod

When creating projected volumes, consider the volume file path situations described in *Understanding projected volumes*.

The following example shows how to use a projected volume to mount an existing secret volume source. The steps can be used to create a user name and password secrets from local files. You then create a pod that runs one container, using a projected volume to mount the secrets into the same shared directory.

The user name and password values can be any valid string that is **base64** encoded.

The following example shows **admin** in base64:

```
$ echo -n "admin" | base64
```

### Example output

```
YWRtaW4=
```

The following example shows the password **1f2d1e2e67df** in base64:

```
$ echo -n "1f2d1e2e67df" | base64
```

### Example output

```
MWYyZDFIMmU2N2Rm
```

### Procedure

To use a projected volume to mount an existing secret volume source.



1. Create the secret:
  - a. Create a YAML file similar to the following, replacing the password and user information as appropriate:

```
apiVersion: v1
kind: Secret
metadata:
  name: mysecret
type: Opaque
data:
  pass: MWYyZDFIMmU2N2Rm
  user: YWRtaW4=
```

- b. Use the following command to create the secret:

```
$ oc create -f <secrets-filename>
```

For example:

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

#### Example output

```
secret "mysecret" created
```

- c. You can check that the secret was created using the following commands:

```
$ oc get secret <secret-name>
```

For example:

```
$ oc get secret mysecret
```

#### Example output

```
NAME      TYPE      DATA   AGE
mysecret  Opaque    2       17h
```

```
$ oc get secret <secret-name> -o yaml
```

For example:

```
$ oc get secret mysecret -o yaml
```

```
apiVersion: v1
data:
  pass: MWYyZDFIMmU2N2Rm
  user: YWRtaW4=
kind: Secret
metadata:
  creationTimestamp: 2017-05-30T20:21:38Z
```

```

name: mysecret
namespace: default
resourceVersion: "2107"
selfLink: /api/v1/namespaces/default/secrets/mysecret
uid: 959e0424-4575-11e7-9f97-fa163e4bd54c
type: Opaque

```

2. Create a pod with a projected volume.

a. Create a YAML file similar to the following, including a **volumes** section:

```

kind: Pod
metadata:
  name: test-projected-volume
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: test-projected-volume
    image: busybox
    args:
    - sleep
    - "86400"
    volumeMounts:
    - name: all-in-one
      mountPath: "/projected-volume"
      readOnly: true
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
  volumes:
  - name: all-in-one
    projected:
      sources:
      - secret:
          name: mysecret 1

```

**1** The name of the secret you created.

b. Create the pod from the configuration file:

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

For example:

```
$ oc create -f secret-pod.yaml
```

### Example output

```
pod "test-projected-volume" created
```

- Verify that the pod container is running, and then watch for changes to the pod:

```
$ oc get pod <name>
```

For example:

```
$ oc get pod test-projected-volume
```

The output should appear similar to the following:

#### Example output

```
NAME                READY   STATUS    RESTARTS  AGE
test-projected-volume 1/1     Running  0         14s
```

- In another terminal, use the **oc exec** command to open a shell to the running container:

```
$ oc exec -it <pod> <command>
```

For example:

```
$ oc exec -it test-projected-volume -- /bin/sh
```

- In your shell, verify that the **projected-volumes** directory contains your projected sources:

```
/ # ls
```

#### Example output

```
bin          home         root         tmp
dev          proc         run          usr
etc          projected-volume sys          var
```

## 7.5. ALLOWING CONTAINERS TO CONSUME API OBJECTS

The *Downward API* is a mechanism that allows containers to consume information about API objects without coupling to OpenShift Container Platform. Such information includes the pod's name, namespace, and resource values. Containers can consume information from the downward API using environment variables or a volume plugin.

### 7.5.1. Expose pod information to Containers using the Downward API

The Downward API contains such information as the pod's name, project, and resource values. Containers can consume information from the downward API using environment variables or a volume plugin.

Fields within the pod are selected using the **FieldRef** API type. **FieldRef** has two fields:

Field	Description
<b>fieldPath</b>	The path of the field to select, relative to the pod.
<b>apiVersion</b>	The API version to interpret the <b>fieldPath</b> selector within.

Currently, the valid selectors in the v1 API include:

Selector	Description
<b>metadata.name</b>	The pod's name. This is supported in both environment variables and volumes.
<b>metadata.namespace</b>	The pod's namespace. This is supported in both environment variables and volumes.
<b>metadata.labels</b>	The pod's labels. This is only supported in volumes and not in environment variables.
<b>metadata.annotations</b>	The pod's annotations. This is only supported in volumes and not in environment variables.
<b>status.podIP</b>	The pod's IP. This is only supported in environment variables and not volumes.

The **apiVersion** field, if not specified, defaults to the API version of the enclosing pod template.

## 7.5.2. Understanding how to consume container values using the downward API

You containers can consume API values using environment variables or a volume plugin. Depending on the method you choose, containers can consume:

- Pod name
- Pod project/namespace
- Pod annotations
- Pod labels

Annotations and labels are available using only a volume plugin.

### 7.5.2.1. Consuming container values using environment variables

When using a container's environment variables, use the **EnvVar** type's **valueFrom** field (of type **EnvVarSource**) to specify that the variable's value should come from a **FieldRef** source instead of the literal value specified by the **value** field.

Only constant attributes of the pod can be consumed this way, as environment variables cannot be updated once a process is started in a way that allows the process to be notified that the value of a variable has changed. The fields supported using environment variables are:

- Pod name
- Pod project/namespace

## Procedure

1. Create a new pod spec that contains the environment variables you want the container to consume:
  - a. Create a **pod.yaml** file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: env-test-container
    image: gcr.io/google_containers/busybox
    command: [ "/bin/sh", "-c", "env" ]
    env:
      - name: MY_POD_NAME
        valueFrom:
          fieldRef:
            fieldPath: metadata.name
      - name: MY_POD_NAMESPACE
        valueFrom:
          fieldRef:
            fieldPath: metadata.namespace
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
    restartPolicy: Never
# ...
```

- b. Create the pod from the **pod.yaml** file:

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

## Verification

- Check the container's logs for the **MY\_POD\_NAME** and **MY\_POD\_NAMESPACE** values:

```
$ oc logs -p dapi-env-test-pod
```

### 7.5.2.2. Consuming container values using a volume plugin

You containers can consume API values using a volume plugin.

Containers can consume:

- Pod name
- Pod project/namespace
- Pod annotations
- Pod labels

#### Procedure

To use the volume plugin:

1. Create a new pod spec that contains the environment variables you want the container to consume:
  - a. Create a **volume-pod.yaml** file similar to the following:

```
kind: Pod
apiVersion: v1
metadata:
  labels:
    zone: us-east-coast
    cluster: downward-api-test-cluster1
    rack: rack-123
  name: dapi-volume-test-pod
  annotations:
    annotation1: "345"
    annotation2: "456"
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - name: volume-test-container
    image: gcr.io/google_containers/busybox
    command: ["sh", "-c", "cat /tmp/etc/pod_labels /tmp/etc/pod_annotations"]
    volumeMounts:
    - name: podinfo
      mountPath: /tmp/etc
      readOnly: false
    securityContext:
      allowPrivilegeEscalation: false
    capabilities:
      drop: [ALL]
  volumes:
  - name: podinfo
    downwardAPI:
      defaultMode: 420
    items:
    - fieldRef:
```

```

    fieldPath: metadata.name
  path: pod_name
- fieldRef:
    fieldPath: metadata.namespace
  path: pod_namespace
- fieldRef:
    fieldPath: metadata.labels
  path: pod_labels
- fieldRef:
    fieldPath: metadata.annotations
  path: pod_annotations
restartPolicy: Never
# ...

```

b. Create the pod from the **volume-pod.yaml** file:

```
$ oc create -f volume-pod.yaml
```

### Verification

- Check the container's logs and verify the presence of the configured fields:

```
$ oc logs -p dapi-volume-test-pod
```

### Example output

```

cluster=downward-api-test-cluster1
rack=rack-123
zone=us-east-coast
annotation1=345
annotation2=456
kubernetes.io/config.source=api

```

## 7.5.3. Understanding how to consume container resources using the Downward API

When creating pods, you can use the Downward API to inject information about computing resource requests and limits so that image and application authors can correctly create an image for specific environments.

You can do this using environment variable or a volume plugin.

### 7.5.3.1. Consuming container resources using environment variables

When creating pods, you can use the Downward API to inject information about computing resource requests and limits using environment variables.

When creating the pod configuration, specify environment variables that correspond to the contents of the **resources** field in the **spec.container** field.



#### NOTE

If the resource limits are not included in the container configuration, the downward API defaults to the node's CPU and memory allocatable values.

## Procedure

1. Create a new pod spec that contains the resources you want to inject:
  - a. Create a **pod.yaml** file similar to the following:

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  containers:
  - name: test-container
    image: gcr.io/google_containers/busybox:1.24
    command: [ "/bin/sh", "-c", "env" ]
    resources:
      requests:
        memory: "32Mi"
        cpu: "125m"
      limits:
        memory: "64Mi"
        cpu: "250m"
    env:
    - name: MY_CPU_REQUEST
      valueFrom:
        resourceFieldRef:
          resource: requests.cpu
    - name: MY_CPU_LIMIT
      valueFrom:
        resourceFieldRef:
          resource: limits.cpu
    - name: MY_MEM_REQUEST
      valueFrom:
        resourceFieldRef:
          resource: requests.memory
    - name: MY_MEM_LIMIT
      valueFrom:
        resourceFieldRef:
          resource: limits.memory
# ...

```

- b. Create the pod from the **pod.yaml** file:

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

### 7.5.3.2. Consuming container resources using a volume plugin

When creating pods, you can use the Downward API to inject information about computing resource requests and limits using a volume plugin.

When creating the pod configuration, use the **spec.volumes.downwardAPI.items** field to describe the desired resources that correspond to the **spec.resources** field.





## NOTE

If the resource limits are not included in the container configuration, the Downward API defaults to the node's CPU and memory allocatable values.

## Procedure

1. Create a new pod spec that contains the resources you want to inject:
  - a. Create a **pod.yaml** file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  containers:
  - name: client-container
    image: gcr.io/google_containers/busybox:1.24
    command: ["sh", "-c", "while true; do echo; if [[ -e /etc/cpu_limit ]]; then cat
/etc/cpu_limit; fi; if [[ -e /etc/cpu_request ]]; then cat /etc/cpu_request; fi; if [[ -e
/etc/mem_limit ]]; then cat /etc/mem_limit; fi; if [[ -e /etc/mem_request ]]; then cat
/etc/mem_request; fi; sleep 5; done"]
    resources:
      requests:
        memory: "32Mi"
        cpu: "125m"
      limits:
        memory: "64Mi"
        cpu: "250m"
    volumeMounts:
    - name: podinfo
      mountPath: /etc
      readOnly: false
  volumes:
  - name: podinfo
    downwardAPI:
      items:
      - path: "cpu_limit"
        resourceFieldRef:
          containerName: client-container
          resource: limits.cpu
      - path: "cpu_request"
        resourceFieldRef:
          containerName: client-container
          resource: requests.cpu
      - path: "mem_limit"
        resourceFieldRef:
          containerName: client-container
          resource: limits.memory
      - path: "mem_request"
        resourceFieldRef:
          containerName: client-container
          resource: requests.memory
# ...
```

- b. Create the pod from the **volume-pod.yaml** file:

```
$ oc create -f volume-pod.yaml
```

#### 7.5.4. Consuming secrets using the Downward API

When creating pods, you can use the downward API to inject secrets so image and application authors can create an image for specific environments.

##### Procedure

1. Create a secret to inject:
  - a. Create a **secret.yaml** file similar to the following:

```
apiVersion: v1
kind: Secret
metadata:
  name: mysecret
data:
  password: <password>
  username: <username>
type: kubernetes.io/basic-auth
```

- b. Create the secret object from the **secret.yaml** file:

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

2. Create a pod that references the **username** field from the above **Secret** object:
  - a. Create a **pod.yaml** file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
    - name: env-test-container
      image: gcr.io/google_containers/busybox
      command: [ "/bin/sh", "-c", "env" ]
      env:
        - name: MY_SECRET_USERNAME
          valueFrom:
            secretKeyRef:
              name: mysecret
              key: username
      securityContext:
        allowPrivilegeEscalation: false
      capabilities:
```

```

    drop: [ALL]
    restartPolicy: Never
# ...

```

- b. Create the pod from the **pod.yaml** file:

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

## Verification

- Check the container's logs for the **MY\_SECRET\_USERNAME** value:

```
$ oc logs -p dapi-env-test-pod
```

## 7.5.5. Consuming configuration maps using the Downward API

When creating pods, you can use the Downward API to inject configuration map values so image and application authors can create an image for specific environments.

### Procedure

1. Create a config map with the values to inject:
  - a. Create a **configmap.yaml** file similar to the following:

```

apiVersion: v1
kind: ConfigMap
metadata:
  name: myconfigmap
data:
  mykey: myvalue

```

- b. Create the config map from the **configmap.yaml** file:

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

2. Create a pod that references the above config map:
  - a. Create a **pod.yaml** file similar to the following:

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
    - name: env-test-container
      image: gcr.io/google_containers/busybox
      command: [ "/bin/sh", "-c", "env" ]
      env:

```

```

- name: MY_CONFIGMAP_VALUE
  valueFrom:
    configMapKeyRef:
      name: myconfigmap
      key: mykey
  securityContext:
    allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]
  restartPolicy: Always
# ...

```

- b. Create the pod from the **pod.yaml** file:

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

## Verification

- Check the container's logs for the **MY\_CONFIGMAP\_VALUE** value:

```
$ oc logs -p dapi-env-test-pod
```

## 7.5.6. Referencing environment variables

When creating pods, you can reference the value of a previously defined environment variable by using the **\$( )** syntax. If the environment variable reference can not be resolved, the value will be left as the provided string.

### Procedure

1. Create a pod that references an existing environment variable:
  - a. Create a **pod.yaml** file similar to the following:

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
    - name: env-test-container
      image: gcr.io/google_containers/busybox
      command: [ "/bin/sh", "-c", "env" ]
      env:
        - name: MY_EXISTING_ENV
          value: my_value
        - name: MY_ENV_VAR_REF_ENV
          value: $(MY_EXISTING_ENV)
      securityContext:
        allowPrivilegeEscalation: false

```

```

capabilities:
  drop: [ALL]
restartPolicy: Never
# ...

```

- b. Create the pod from the **pod.yaml** file:

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

## Verification

- Check the container's logs for the **MY\_ENV\_VAR\_REF\_ENV** value:

```
$ oc logs -p dapi-env-test-pod
```

## 7.5.7. Escaping environment variable references

When creating a pod, you can escape an environment variable reference by using a double dollar sign. The value will then be set to a single dollar sign version of the provided value.

### Procedure

1. Create a pod that references an existing environment variable:
  - a. Create a **pod.yaml** file similar to the following:

```

apiVersion: v1
kind: Pod
metadata:
  name: dapi-env-test-pod
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: env-test-container
    image: gcr.io/google_containers/busybox
    command: [ "/bin/sh", "-c", "env" ]
    env:
    - name: MY_NEW_ENV
      value: $$SOME_OTHER_ENV
    securityContext:
      allowPrivilegeEscalation: false
      capabilities:
        drop: [ALL]
    restartPolicy: Never
# ...

```

- b. Create the pod from the **pod.yaml** file:

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

## Verification

- Check the container's logs for the **MY\_NEW\_ENV** value:

```
$ oc logs -p dapi-env-test-pod
```

## 7.6. COPYING FILES TO OR FROM AN OPENSIFT CONTAINER PLATFORM CONTAINER

You can use the CLI to copy local files to or from a remote directory in a container using the **rsync** command.

### 7.6.1. Understanding how to copy files

The **oc rsync** command, or remote sync, is a useful tool for copying database archives to and from your pods for backup and restore purposes. You can also use **oc rsync** to copy source code changes into a running pod for development debugging, when the running pod supports hot reload of source files.

```
$ oc rsync <source> <destination> [-c <container>]
```

#### 7.6.1.1. Requirements

##### Specifying the Copy Source

The source argument of the **oc rsync** command must point to either a local directory or a pod directory. Individual files are not supported.

When specifying a pod directory the directory name must be prefixed with the pod name:

```
<pod name>:<dir>
```

If the directory name ends in a path separator (*/*), only the contents of the directory are copied to the destination. Otherwise, the directory and its contents are copied to the destination.

##### Specifying the Copy Destination

The destination argument of the **oc rsync** command must point to a directory. If the directory does not exist, but **rsync** is used for copy, the directory is created for you.

##### Deleting Files at the Destination

The **--delete** flag may be used to delete any files in the remote directory that are not in the local directory.

##### Continuous Syncing on File Change

Using the **--watch** option causes the command to monitor the source path for any file system changes, and synchronizes changes when they occur. With this argument, the command runs forever. Synchronization occurs after short quiet periods to ensure a rapidly changing file system does not result in continuous synchronization calls.

When using the **--watch** option, the behavior is effectively the same as manually invoking **oc rsync** repeatedly, including any arguments normally passed to **oc rsync**. Therefore, you can control the behavior via the same flags used with manual invocations of **oc rsync**, such as **--delete**.

### 7.6.2. Copying files to and from containers

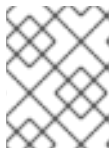
Support for copying local files to or from a container is built into the CLI.

## Prerequisites

When working with **oc rsync**, note the following:

- **rsync** must be installed. The **oc rsync** command uses the local **rsync** tool, if present on the client machine and the remote container.  
If **rsync** is not found locally or in the remote container, a **tar** archive is created locally and sent to the container where the **tar** utility is used to extract the files. If **tar** is not available in the remote container, the copy will fail.

The **tar** copy method does not provide the same functionality as **oc rsync**. For example, **oc rsync** creates the destination directory if it does not exist and only sends files that are different between the source and the destination.



### NOTE

In Windows, the **cwRsync** client should be installed and added to the PATH for use with the **oc rsync** command.

## Procedure

- To copy a local directory to a pod directory:

```
$ oc rsync <local-dir> <pod-name>:<remote-dir> -c <container-name>
```

For example:

```
$ oc rsync /home/user/source devpod1234:/src -c user-container
```

- To copy a pod directory to a local directory:

```
$ oc rsync devpod1234:/src /home/user/source
```

### Example output

```
$ oc rsync devpod1234:/src/status.txt /home/user/
```

### 7.6.3. Using advanced Rsync features

The **oc rsync** command exposes fewer command line options than standard **rsync**. In the case that you want to use a standard **rsync** command line option that is not available in **oc rsync**, for example the **--exclude-from=FILE** option, it might be possible to use standard **rsync**'s **--rsh (-e)** option or **RSYNC\_RSH** environment variable as a workaround, as follows:

```
$ rsync --rsh='oc rsh' --exclude-from=<file_name> <local-dir> <pod-name>:<remote-dir>
```

or:

Export the **RSYNC\_RSH** variable:

```
$ export RSYNC_RSH='oc rsh'
```

Then, run the `rsync` command:

```
$ rsync --exclude-from=<file_name> <local-dir> <pod-name>:./<remote-dir>
```

Both of the above examples configure standard **rsync** to use **oc rsh** as its remote shell program to enable it to connect to the remote pod, and are an alternative to running **oc rsync**.

## 7.7. EXECUTING REMOTE COMMANDS IN AN OPENSIFT CONTAINER PLATFORM CONTAINER

You can use the CLI to execute remote commands in an OpenShift Container Platform container.

### 7.7.1. Executing remote commands in containers

Support for remote container command execution is built into the CLI.

#### Procedure

To run a command in a container:

```
$ oc exec <pod> [-c <container>] -- <command> [<arg_1> ... <arg_n>]
```

For example:

```
$ oc exec mypod date
```

#### Example output

```
Thu Apr 9 02:21:53 UTC 2015
```



#### IMPORTANT

For security purposes, the **oc exec** command does not work when accessing privileged containers except when the command is executed by a **cluster-admin** user.

### 7.7.2. Protocol for initiating a remote command from a client

Clients initiate the execution of a remote command in a container by issuing a request to the Kubernetes API server:

```
/proxy/nodes/<node_name>/exec/<namespace>/<pod>/<container>?command=<command>
```

In the above URL:

- **<node\_name>** is the FQDN of the node.
- **<namespace>** is the project of the target pod.
- **<pod>** is the name of the target pod.
- **<container>** is the name of the target container.



- **<command>** is the desired command to be executed.

For example:

```
/proxy/nodes/node123.openshift.com/exec/myns/mypod/mycontainer?command=date
```

Additionally, the client can add parameters to the request to indicate if:

- the client should send input to the remote container's command (stdin).
- the client's terminal is a TTY.
- the remote container's command should send output from stdout to the client.
- the remote container's command should send output from stderr to the client.

After sending an **exec** request to the API server, the client upgrades the connection to one that supports multiplexed streams; the current implementation uses **HTTP/2**.

The client creates one stream each for stdin, stdout, and stderr. To distinguish among the streams, the client sets the **streamType** header on the stream to one of **stdin**, **stdout**, or **stderr**.

The client closes all streams, the upgraded connection, and the underlying connection when it is finished with the remote command execution request.

## 7.8. USING PORT FORWARDING TO ACCESS APPLICATIONS IN A CONTAINER

OpenShift Container Platform supports port forwarding to pods.

### 7.8.1. Understanding port forwarding

You can use the CLI to forward one or more local ports to a pod. This allows you to listen on a given or random port locally, and have data forwarded to and from given ports in the pod.

Support for port forwarding is built into the CLI:

```
$ oc port-forward <pod> [<local_port>:]<remote_port> [...[<local_port_n>:]<remote_port_n>]
```

The CLI listens on each local port specified by the user, forwarding using the protocol described below.

Ports may be specified using the following formats:

<b>5000</b>	The client listens on port 5000 locally and forwards to 5000 in the pod.
<b>6000:5000</b>	The client listens on port 6000 locally and forwards to 5000 in the pod.
<b>:5000</b> or <b>0:5000</b>	The client selects a free local port and forwards to 5000 in the pod.

OpenShift Container Platform handles port-forward requests from clients. Upon receiving a request, OpenShift Container Platform upgrades the response and waits for the client to create port-forwarding

streams. When OpenShift Container Platform receives a new stream, it copies data between the stream and the pod's port.

Architecturally, there are options for forwarding to a pod's port. The supported OpenShift Container Platform implementation invokes **nsenter** directly on the node host to enter the pod's network namespace, then invokes **socat** to copy data between the stream and the pod's port. However, a custom implementation could include running a *helper* pod that then runs **nsenter** and **socat**, so that those binaries are not required to be installed on the host.

## 7.8.2. Using port forwarding

You can use the CLI to port-forward one or more local ports to a pod.

### Procedure

Use the following command to listen on the specified port in a pod:

```
$ oc port-forward <pod> [<local_port>:]<remote_port> [...[<local_port_n>:]<remote_port_n>]
```

For example:

- Use the following command to listen on ports **5000** and **6000** locally and forward data to and from ports **5000** and **6000** in the pod:

```
$ oc port-forward <pod> 5000 6000
```

### Example output

```
Forwarding from 127.0.0.1:5000 -> 5000
Forwarding from [::1]:5000 -> 5000
Forwarding from 127.0.0.1:6000 -> 6000
Forwarding from [::1]:6000 -> 6000
```

- Use the following command to listen on port **8888** locally and forward to **5000** in the pod:

```
$ oc port-forward <pod> 8888:5000
```

### Example output

```
Forwarding from 127.0.0.1:8888 -> 5000
Forwarding from [::1]:8888 -> 5000
```

- Use the following command to listen on a free port locally and forward to **5000** in the pod:

```
$ oc port-forward <pod> :5000
```

### Example output

```
Forwarding from 127.0.0.1:42390 -> 5000
Forwarding from [::1]:42390 -> 5000
```

Or:

■

```
$ oc port-forward <pod> 0:5000
```

### 7.8.3. Protocol for initiating port forwarding from a client

Clients initiate port forwarding to a pod by issuing a request to the Kubernetes API server:

```
/proxy/nodes/<node_name>/portForward/<namespace>/<pod>
```

In the above URL:

- **<node\_name>** is the FQDN of the node.
- **<namespace>** is the namespace of the target pod.
- **<pod>** is the name of the target pod.

For example:

```
/proxy/nodes/node123.openshift.com/portForward/myns/mypod
```

After sending a port forward request to the API server, the client upgrades the connection to one that supports multiplexed streams; the current implementation uses [Hypertext Transfer Protocol Version 2 \(HTTP/2\)](#).

The client creates a stream with the **port** header containing the target port in the pod. All data written to the stream is delivered via the kubelet to the target pod and port. Similarly, all data sent from the pod for that forwarded connection is delivered back to the same stream in the client.

The client closes all streams, the upgraded connection, and the underlying connection when it is finished with the port forwarding request.

## 7.9. USING SYSCTLS IN CONTAINERS

Sysctl settings are exposed through Kubernetes, allowing users to modify certain kernel parameters at runtime. Only sysctls that are namespaced can be set independently on pods. If a sysctl is not namespaced, called *node-level*, you must use another method of setting the sysctl, such as by using the Node Tuning Operator.

Network sysctls are a special category of sysctl. Network sysctls include:

- System-wide sysctls, for example **net.ipv4.ip\_local\_port\_range**, that are valid for all networking. You can set these independently for each pod on a node.
- Interface-specific sysctls, for example **net.ipv4.conf.IFNAME.accept\_local**, that only apply to a specific additional network interface for a given pod. You can set these independently for each additional network configuration. You set these by using a configuration in the **tuning-cni** after the network interfaces are created.

Moreover, only those sysctls considered *safe* are whitelisted by default; you can manually enable other *unsafe* sysctls on the node to be available to the user.

If you are setting the sysctl and it is not node-level, you can find information on this procedure in the section [Using the Node Tuning Operator](#).

### 7.9.1. About sysctls

In Linux, the `sysctl` interface allows an administrator to modify kernel parameters at runtime. Parameters are available from the `/proc/sys/` virtual process file system. The parameters cover various subsystems, such as:

- kernel (common prefix: ***kernel.***)
- networking (common prefix: ***net.***)
- virtual memory (common prefix: ***vm.***)
- MDADM (common prefix: ***dev.***)

More subsystems are described in [Kernel documentation](#). To get a list of all parameters, run:

```
$ sudo sysctl -a
```

### 7.9.2. Namespaced and node-level sysctls

A number of sysctls are *namespaced* in the Linux kernels. This means that you can set them independently for each pod on a node. Being namespaced is a requirement for sysctls to be accessible in a pod context within Kubernetes.

The following sysctls are known to be namespaced:

- ***kernel.shm\****
- ***kernel.msg\****
- ***kernel.sem***
- ***fs.mqueue.\****

Additionally, most of the sysctls in the ***net.\**** group are known to be namespaced. Their namespace adoption differs based on the kernel version and distributor.

Sysctls that are not namespaced are called *node-level* and must be set manually by the cluster administrator, either by means of the underlying Linux distribution of the nodes, such as by modifying the `/etc/sysctls.conf` file, or by using a daemon set with privileged containers. You can use the Node Tuning Operator to set *node-level* sysctls.



#### NOTE

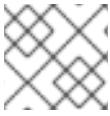
Consider marking nodes with special sysctls as tainted. Only schedule pods onto them that need those sysctl settings. Use the taints and toleration feature to mark the nodes.

### 7.9.3. Safe and unsafe sysctls

Sysctls are grouped into *safe* and *unsafe* sysctls.

For system-wide sysctls to be considered safe, they must be namespaced. A namespaced sysctl ensures there is isolation between namespaces and therefore pods. If you set a sysctl for one pod it must not add any of the following:

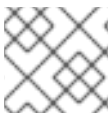
- Influence any other pod on the node
- Harm the node health
- Gain CPU or memory resources outside of the resource limits of a pod

**NOTE**

Being namespaced alone is not sufficient for the sysctl to be considered safe.

Any sysctl that is not added to the allowed list on OpenShift Container Platform is considered unsafe for OpenShift Container Platform.

Unsafe sysctls are not allowed by default. For system-wide sysctls the cluster administrator must manually enable them on a per-node basis. Pods with disabled unsafe sysctls are scheduled but do not launch.

**NOTE**

You cannot manually enable interface-specific unsafe sysctls.

OpenShift Container Platform adds the following system-wide and interface-specific safe sysctls to an allowed safe list:

**Table 7.4. System-wide safe sysctls**

sysctl	Description
<b>kernel.shm_rmid_forced</b>	When set to <b>1</b> , all shared memory objects in current IPC namespace are automatically forced to use IPC_RMID. For more information, see <a href="#">shm_rmid_forced</a> .
<b>net.ipv4.ip_local_port_range</b>	Defines the local port range that is used by TCP and UDP to choose the local port. The first number is the first port number, and the second number is the last local port number. If possible, it is better if these numbers have different parity (one even and one odd value). They must be greater than or equal to <b>ip_unprivileged_port_start</b> . The default values are <b>32768</b> and <b>60999</b> respectively. For more information, see <a href="#">ip_local_port_range</a> .
<b>net.ipv4.tcp_syncookies</b>	When <b>net.ipv4.tcp_syncookies</b> is set, the kernel handles TCP SYN packets normally until the half-open connection queue is full, at which time, the SYN cookie functionality kicks in. This functionality allows the system to keep accepting valid connections, even if under a denial-of-service attack. For more information, see <a href="#">tcp_syncookies</a> .
<b>net.ipv4.ping_group_range</b>	This restricts <b>ICMP_PROTO</b> datagram sockets to users in the group range. The default is <b>1 0</b> , meaning that nobody, not even root, can create ping sockets. For more information, see <a href="#">ping_group_range</a> .

sysctl	Description
<b>net.ipv4.ip_unprivileged_port_start</b>	This defines the first unprivileged port in the network namespace. To disable all privileged ports, set this to <b>0</b> . Privileged ports must not overlap with the <b>ip_local_port_range</b> . For more information, see <a href="#">ip_unprivileged_port_start</a> .
<b>net.ipv4.ip_local_reserved_ports</b>	Specify a range of comma-separated local ports that you want to reserve for applications or services.
<b>net.ipv4.tcp_keepalive_time</b>	Specify the interval in seconds before the first <b>keepalive</b> probe should be sent after a connection has become idle.
<b>net.ipv4.tcp_fin_timeout</b>	Specify the time in seconds that a connection remains in the <b>FIN-WAIT-2</b> state before it is aborted.
<b>net.ipv4.tcp_keepalive_intvl</b>	Specify the interval in seconds between the <b>keepalive</b> probes. This value is multiplied by the <b>tcp_keepalive_probes</b> value to determine the total time required before it is decided that the connection is broken.
<b>net.ipv4.tcp_keepalive_probes</b>	Specify how many <b>keepalive</b> probes to send until it is determined that the connection is broken.

Table 7.5. Interface-specific safe sysctls

sysctl	Description
<b>net.ipv4.conf.IFNAME.accept_redirects</b>	Accept IPv4 ICMP redirect messages.
<b>net.ipv4.conf.IFNAME.accept_source_route</b>	Accept IPv4 packets with strict source route (SRR) option.
<b>net.ipv4.conf.IFNAME.arp_accept</b>	Define behavior for gratuitous ARP frames with an IPv4 address that is not already present in the ARP table: <ul style="list-style-type: none"> <li>● <b>0</b> - Do not create new entries in the ARP table.</li> <li>● <b>1</b> - Create new entries in the ARP table.</li> </ul>
<b>net.ipv4.conf.IFNAME.arp_notify</b>	Define mode for notification of IPv4 address and device changes.
<b>net.ipv4.conf.IFNAME.disable_policy</b>	Disable IPSEC policy (SPD) for this IPv4 interface.
<b>net.ipv4.conf.IFNAME.secure_redirects</b>	Accept ICMP redirect messages only to gateways listed in the interface's current gateway list.

sysctl	Description
<b>net.ipv4.conf.IFNAME.send_redirects</b>	Send redirects is enabled only if the node acts as a router. That is, a host should not send an ICMP redirect message. It is used by routers to notify the host about a better routing path that is available for a particular destination.
<b>net.ipv6.conf.IFNAME.accept_ra</b>	Accept IPv6 Router advertisements; autoconfigure using them. It also determines whether or not to transmit router solicitations. Router solicitations are transmitted only if the functional setting is to accept router advertisements.
<b>net.ipv6.conf.IFNAME.accept_redirects</b>	Accept IPv6 ICMP redirect messages.
<b>net.ipv6.conf.IFNAME.accept_source_route</b>	Accept IPv6 packets with SRR option.
<b>net.ipv6.conf.IFNAME.arp_accept</b>	Define behavior for gratuitous ARP frames with an IPv6 address that is not already present in the ARP table: <ul style="list-style-type: none"> <li>● <b>0</b> - Do not create new entries in the ARP table.</li> <li>● <b>1</b> - Create new entries in the ARP table.</li> </ul>
<b>net.ipv6.conf.IFNAME.arp_notify</b>	Define mode for notification of IPv6 address and device changes.
<b>net.ipv6.neigh.IFNAME.base_reachable_time_ms</b>	This parameter controls the hardware address to IP mapping lifetime in the neighbour table for IPv6.
<b>net.ipv6.neigh.IFNAME.retrans_time_ms</b>	Set the retransmit timer for neighbor discovery messages.

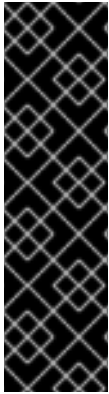


#### NOTE

When setting these values using the **tuning** CNI plugin, use the value **IFNAME** literally. The interface name is represented by the **IFNAME** token, and is replaced with the actual name of the interface at runtime.

#### 7.9.4. Updating the interface-specific safe sysctls list

OpenShift Container Platform includes a predefined list of safe interface-specific **sysctls**. You can modify this list by updating the **cni-sysctl-allowlist** in the **openshift-multus** namespace.



## IMPORTANT

The support for updating the interface-specific safe sysctls list 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](#).

Follow this procedure to modify the predefined list of safe **sysctls**. This procedure describes how to extend the default allow list.

### Procedure

1. View the existing predefined list by running the following command:

```
$ oc get cm -n openshift-multus cni-sysctl-allowlist -oyaml
```

### Expected output

```
apiVersion: v1
data:
  allowlist.conf: |-
    ^net.ipv4.conf.IFNAME.accept_redirects$
    ^net.ipv4.conf.IFNAME.accept_source_route$
    ^net.ipv4.conf.IFNAME.arp_accept$
    ^net.ipv4.conf.IFNAME.arp_notify$
    ^net.ipv4.conf.IFNAME.disable_policy$
    ^net.ipv4.conf.IFNAME.secure_redirects$
    ^net.ipv4.conf.IFNAME.send_redirects$
    ^net.ipv6.conf.IFNAME.accept_ra$
    ^net.ipv6.conf.IFNAME.accept_redirects$
    ^net.ipv6.conf.IFNAME.accept_source_route$
    ^net.ipv6.conf.IFNAME.arp_accept$
    ^net.ipv6.conf.IFNAME.arp_notify$
    ^net.ipv6.neigh.IFNAME.base_reachable_time_ms$
    ^net.ipv6.neigh.IFNAME.retrans_time_ms$
kind: ConfigMap
metadata:
  annotations:
    kubernetes.io/description: |
      Sysctl allowlist for nodes.
    release.openshift.io/version: 4.17.0-0.nightly-2022-11-16-003434
  creationTimestamp: "2022-11-17T14:09:27Z"
  name: cni-sysctl-allowlist
  namespace: openshift-multus
  resourceVersion: "2422"
  uid: 96d138a3-160e-4943-90ff-6108fa7c50c3
```

2. Edit the list by using the following command:



```
$ oc edit cm -n openshift-multus cni-sysctl-allowlist -oyaml
```

For example, to allow you to be able to implement stricter reverse path forwarding you need to add `^net.ipv4.conf.IFNAME.rp_filter$` and `^net.ipv6.conf.IFNAME.rp_filter$` to the list as shown here:

```
# Please edit the object below. Lines beginning with a '#' will be ignored,
# and an empty file will abort the edit. If an error occurs while saving this file will be
# reopened with the relevant failures.
#
apiVersion: v1
data:
  allowlist.conf: |-
    ^net.ipv4.conf.IFNAME.accept_redirects$
    ^net.ipv4.conf.IFNAME.accept_source_route$
    ^net.ipv4.conf.IFNAME.arp_accept$
    ^net.ipv4.conf.IFNAME.arp_notify$
    ^net.ipv4.conf.IFNAME.disable_policy$
    ^net.ipv4.conf.IFNAME.secure_redirects$
    ^net.ipv4.conf.IFNAME.send_redirects$
    ^net.ipv4.conf.IFNAME.rp_filter$
    ^net.ipv6.conf.IFNAME.accept_ra$
    ^net.ipv6.conf.IFNAME.accept_redirects$
    ^net.ipv6.conf.IFNAME.accept_source_route$
    ^net.ipv6.conf.IFNAME.arp_accept$
    ^net.ipv6.conf.IFNAME.arp_notify$
    ^net.ipv6.neigh.IFNAME.base_reachable_time_ms$
    ^net.ipv6.neigh.IFNAME.retrans_time_ms$
    ^net.ipv6.conf.IFNAME.rp_filter$
```

3. Save the changes to the file and exit.



## NOTE

The removal of **sysctls** is also supported. Edit the file, remove the **sysctl** or **sysctls** then save the changes and exit.

## Verification

Follow this procedure to enforce stricter reverse path forwarding for IPv4. For more information on reverse path forwarding see [Reverse Path Forwarding](#) .

1. Create a network attachment definition, such as **reverse-path-fwd-example.yaml**, with the following content:

```
apiVersion: "k8s.cni.cncf.io/v1"
kind: NetworkAttachmentDefinition
metadata:
  name: tuningnad
  namespace: default
spec:
  config: '{
    "cniVersion": "0.4.0",
    "name": "tuningnad",
    "plugins": [{
```

```

    "type": "bridge"
  },
  {
    "type": "tuning",
    "sysctl": {
      "net.ipv4.conf.IFNAME.rp_filter": "1"
    }
  }
]
}'

```

- Apply the yaml by running the following command:

```
$ oc apply -f reverse-path-fwd-example.yaml
```

### Example output

```
networkattachmentdefinition.k8s.cni.cncf.io/tuningnad created
```

- Create a pod such as **examplepod.yaml** using the following YAML:

```

apiVersion: v1
kind: Pod
metadata:
  name: example
  labels:
    app: httpd
  namespace: default
  annotations:
    k8s.v1.cni.cncf.io/networks: tuningnad 1
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
    - name: httpd
      image: 'image-registry.openshift-image-registry.svc:5000/openshift/httpd:latest'
      ports:
        - containerPort: 8080
      securityContext:
        allowPrivilegeEscalation: false
      capabilities:
        drop:
          - ALL

```

- Specify the name of the configured **NetworkAttachmentDefinition**.

- Apply the yaml by running the following command:

```
$ oc apply -f examplepod.yaml
```

- Verify that the pod is created by running the following command:

```
$ oc get pod
```

### Example output

```
NAME    READY  STATUS   RESTARTS  AGE
example 1/1    Running  0         47s
```

- Log in to the pod by running the following command:

```
$ oc rsh example
```

- Verify the value of the configured sysctl flag. For example, find the value **net.ipv4.conf.net1.rp\_filter** by running the following command:

```
sh-4.4# sysctl net.ipv4.conf.net1.rp_filter
```

### Expected output

```
net.ipv4.conf.net1.rp_filter = 1
```

### Additional resources

- [Linux networking documentation](#)

## 7.9.5. Starting a pod with safe sysctls

You can set sysctls on pods using the pod's **securityContext**. The **securityContext** applies to all containers in the same pod.

Safe sysctls are allowed by default.

This example uses the pod **securityContext** to set the following safe sysctls:

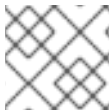
- **kernel.shm\_rmid\_forced**
- **net.ipv4.ip\_local\_port\_range**
- **net.ipv4.tcp\_syncookies**
- **net.ipv4.ping\_group\_range**



### WARNING

To avoid destabilizing your operating system, modify sysctl parameters only after you understand their effects.

Use this procedure to start a pod with the configured sysctl settings.



## NOTE

In most cases you modify an existing pod definition and add the **securityContext** spec.

### Procedure

1. Create a YAML file **sysctl\_pod.yaml** that defines an example pod and add the **securityContext** spec, as shown in the following example:

```
apiVersion: v1
kind: Pod
metadata:
  name: sysctl-example
  namespace: default
spec:
  containers:
  - name: podexample
    image: centos
    command: ["bin/bash", "-c", "sleep INF"]
    securityContext:
      runAsUser: 2000 1
      runAsGroup: 3000 2
      allowPrivilegeEscalation: false 3
      capabilities: 4
      drop: ["ALL"]
    securityContext:
      runAsNonRoot: true 5
      seccompProfile: 6
      type: RuntimeDefault
    sysctls:
      - name: kernel.shm_rmid_forced
        value: "1"
      - name: net.ipv4.ip_local_port_range
        value: "32770 60666"
      - name: net.ipv4.tcp_syncookies
        value: "0"
      - name: net.ipv4.ping_group_range
        value: "0 200000000"
```

- 1 **runAsUser** controls which user ID the container is run with.
- 2 **runAsGroup** controls which primary group ID the containers is run with.
- 3 **allowPrivilegeEscalation** determines if a pod can request to allow privilege escalation. If unspecified, it defaults to true. This boolean directly controls whether the **no\_new\_privs** flag gets set on the container process.
- 4 **capabilities** permit privileged actions without giving full root access. This policy ensures all capabilities are dropped from the pod.
- 5 **runAsNonRoot: true** requires that the container will run with a user with any UID other than 0.
- 6 **RuntimeDefault** enables the default seccomp profile for a pod or container workload.

2. Create the pod by running the following command:

```
$ oc apply -f sysctl_pod.yaml
```

3. Verify that the pod is created by running the following command:

```
$ oc get pod
```

#### Example output

```
NAME          READY  STATUS   RESTARTS  AGE
sysctl-example 1/1    Running  0         14s
```

4. Log in to the pod by running the following command:

```
$ oc rsh sysctl-example
```

5. Verify the values of the configured sysctl flags. For example, find the value **kernel.shm\_rmid\_forced** by running the following command:

```
sh-4.4# sysctl kernel.shm_rmid_forced
```

#### Expected output

```
kernel.shm_rmid_forced = 1
```

### 7.9.6. Starting a pod with unsafe sysctls

A pod with unsafe sysctls fails to launch on any node unless the cluster administrator explicitly enables unsafe sysctls for that node. As with node-level sysctls, use the taints and toleration feature or labels on nodes to schedule those pods onto the right nodes.

The following example uses the pod **securityContext** to set a safe sysctl **kernel.shm\_rmid\_forced** and two unsafe sysctls, **net.core.somaxconn** and **kernel.msgmax**. There is no distinction between *safe* and *unsafe* sysctls in the specification.



#### WARNING

To avoid destabilizing your operating system, modify sysctl parameters only after you understand their effects.

The following example illustrates what happens when you add safe and unsafe sysctls to a pod specification:

#### Procedure

1. Create a YAML file **sysctl-example-unsafe.yaml** that defines an example pod and add the **securityContext** specification, as shown in the following example:

```

apiVersion: v1
kind: Pod
metadata:
  name: sysctl-example-unsafe
spec:
  containers:
  - name: podexample
    image: centos
    command: ["bin/bash", "-c", "sleep INF"]
    securityContext:
      runAsUser: 2000
      runAsGroup: 3000
      allowPrivilegeEscalation: false
      capabilities:
        drop: ["ALL"]
    securityContext:
      runAsNonRoot: true
      seccompProfile:
        type: RuntimeDefault
    sysctls:
      - name: kernel.shm_rmid_forced
        value: "0"
      - name: net.core.somaxconn
        value: "1024"
      - name: kernel.msgmax
        value: "65536"

```

2. Create the pod using the following command:

```
$ oc apply -f sysctl-example-unsafe.yaml
```

3. Verify that the pod is scheduled but does not deploy because unsafe sysctls are not allowed for the node using the following command:

```
$ oc get pod
```

### Example output

NAME	READY	STATUS	RESTARTS	AGE
sysctl-example-unsafe	0/1	SysctlForbidden	0	14s

## 7.9.7. Enabling unsafe sysctls

A cluster administrator can allow certain unsafe sysctls for very special situations such as high performance or real-time application tuning.

If you want to use unsafe sysctls, a cluster administrator must enable them individually for a specific type of node. The sysctls must be namespaced.

You can further control which sysctls are set in pods by specifying lists of sysctls or sysctl patterns in the **allowedUnsafeSysctls** field of the Security Context Constraints.

- The **allowedUnsafeSysctls** option controls specific needs such as high performance or real-time application tuning.



### WARNING

Due to their nature of being unsafe, the use of unsafe sysctls is at-your-own-risk and can lead to severe problems, such as improper behavior of containers, resource shortage, or breaking a node.

### Procedure

1. List existing MachineConfig objects for your OpenShift Container Platform cluster to decide how to label your machine config by running the following command:

```
$ oc get machineconfigpool
```

#### Example output

```
NAME CONFIG UPDATED UPDATING DEGRADED
MACHINECOUNT READYMACHINECOUNT UPDATEDMACHINECOUNT
DEGRADEDMACHINECOUNT AGE
master rendered-master-bfb92f0cd1684e54d8e234ab7423cc96 True False False
3 3 3 0 42m
worker rendered-worker-21b6cb9a0f8919c88caf39db80ac1fce True False False
3 3 3 0 42m
```

2. Add a label to the machine config pool where the containers with the unsafe sysctls will run by running the following command:

```
$ oc label machineconfigpool worker custom-kubelet=sysctl
```

3. Create a YAML file **set-sysctl-worker.yaml** that defines a **KubeletConfig** custom resource (CR):

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: custom-kubelet
spec:
  machineConfigPoolSelector:
    matchLabels:
      custom-kubelet: sysctl 1
  kubeletConfig:
    allowedUnsafeSysctls: 2
      - "kernel.msg*"
      - "net.core.somaxconn"
```

- 1** Specify the label from the machine config pool.

- 2 List the unsafe sysctls you want to allow.

4. Create the object by running the following command:

```
$ oc apply -f set-sysctl-worker.yaml
```

5. Wait for the Machine Config Operator to generate the new rendered configuration and apply it to the machines by running the following command:

```
$ oc get machineconfigpool worker -w
```

After some minutes the **UPDATING** status changes from True to False:

NAME	CONFIG	UPDATED	UPDATING	DEGRADED
MACHINECOUNT	READYMACHINECOUNT	UPDATEDMACHINECOUNT		
DEGRADEDMACHINECOUNT	AGE			
worker	rendered-worker-f1704a00fc6f30d3a7de9a15fd68a800	False	True	False
3	2	2	0	71m
worker	rendered-worker-f1704a00fc6f30d3a7de9a15fd68a800	False	True	False
3	2	3	0	72m
worker	rendered-worker-0188658afe1f3a183ec8c4f14186f4d5	True	False	False
3	3	3	0	72m

6. Create a YAML file **sysctl-example-safe-unsafe.yaml** that defines an example pod and add the **securityContext** spec, as shown in the following example:

```
apiVersion: v1
kind: Pod
metadata:
  name: sysctl-example-safe-unsafe
spec:
  containers:
  - name: podexample
    image: centos
    command: ["bin/bash", "-c", "sleep INF"]
    securityContext:
      runAsUser: 2000
      runAsGroup: 3000
      allowPrivilegeEscalation: false
      capabilities:
        drop: ["ALL"]
    securityContext:
      runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  sysctls:
  - name: kernel.shm_rmid_forced
    value: "0"
  - name: net.core.somaxconn
    value: "1024"
  - name: kernel.msgmax
    value: "65536"
```

7. Create the pod by running the following command:



```
$ oc apply -f sysctl-example-safe-unsafe.yaml
```

### Expected output

```
Warning: would violate PodSecurity "restricted:latest": forbidden sysctls
(net.core.somaxconn, kernel.msgmax)
pod/sysctl-example-safe-unsafe created
```

8. Verify that the pod is created by running the following command:

```
$ oc get pod
```

### Example output

```
NAME                READY STATUS RESTARTS AGE
sysctl-example-safe-unsafe 1/1 Running 0      19s
```

9. Log in to the pod by running the following command:

```
$ oc rsh sysctl-example-safe-unsafe
```

10. Verify the values of the configured sysctl flags. For example, find the value **net.core.somaxconn** by running the following command:

```
sh-4.4# sysctl net.core.somaxconn
```

### Expected output

```
net.core.somaxconn = 1024
```

The unsafe sysctl is now allowed and the value is set as defined in the **securityContext** spec of the updated pod specification.

## 7.9.8. Additional resources

- [Configuring system controls by using the tuning CNI](#)
- [Using the Node Tuning Operator](#)

## 7.10. ACCESSING FASTER BUILDS WITH /DEV/FUSE

You can configure your pods with the **/dev/fuse** device to access faster builds.

### 7.10.1. Configuring /dev/fuse on unprivileged pods

As an alternative to the virtual filesystem, you can configure the **/dev/fuse** device to the **io.kubernetes.cri-o.Devices** annotation to access faster builds within unprivileged pods. Using **/dev/fuse** is secure, efficient, and scalable, and allows unprivileged users to mount an overlay filesystem as if the unprivileged pod was privileged.

#### Procedure

1. Create the pod.

```
$ oc exec -ti no-priv -- /bin/bash
```

```
$ cat >> Dockerfile <<EOF  
FROM registry.access.redhat.com/ubi9  
EOF
```

```
$ podman build .
```

2. Implement **/dev/fuse** by adding the **/dev/fuse** device to the **io.kubernetes.cri-o.Devices** annotation.

```
io.kubernetes.cri-o.Devices: "/dev/fuse"
```

For example:

```
apiVersion: v1  
kind: Pod  
metadata:  
  name: podman-pod  
  annotations:  
    io.kubernetes.cri-o.Devices: "/dev/fuse"
```

3. Configure the **/dev/fuse** device in your pod specifications.

```
spec:  
  containers:  
  - name: podman-container  
    image: quay.io/podman/stable  
    args:  
    - sleep  
    - "1000000"  
    securityContext:  
      runAsUser: 1000
```

## CHAPTER 8. WORKING WITH CLUSTERS

### 8.1. VIEWING SYSTEM EVENT INFORMATION IN AN OPENSIFT CONTAINER PLATFORM CLUSTER

Events in OpenShift Container Platform are modeled based on events that happen to API objects in an OpenShift Container Platform cluster.

#### 8.1.1. Understanding events

Events allow OpenShift Container Platform to record information about real-world events in a resource-agnostic manner. They also allow developers and administrators to consume information about system components in a unified way.

#### 8.1.2. Viewing events using the CLI

You can get a list of events in a given project using the CLI.

##### Procedure

- To view events in a project use the following command:

```
$ oc get events [-n <project>] 1
```

- 1** The name of the project.

For example:

```
$ oc get events -n openshift-config
```

##### Example output

```
LAST SEEN   TYPE      REASON          OBJECT                                     MESSAGE
97m         Normal    Scheduled       pod/dapi-env-test-pod                    Successfully assigned
openshift-config/dapi-env-test-pod to ip-10-0-171-202.ec2.internal
97m         Normal    Pulling        pod/dapi-env-test-pod                    pulling image
"gcr.io/google_containers/busybox"
97m         Normal    Pulled         pod/dapi-env-test-pod                    Successfully pulled image
"gcr.io/google_containers/busybox"
97m         Normal    Created        pod/dapi-env-test-pod                    Created container
9m5s       Warning   FailedCreatePodSandBox pod/dapi-volume-test-pod                Failed create
pod sandbox: rpc error: code = Unknown desc = failed to create pod network sandbox
k8s_dapi-volume-test-pod_openshift-config_6bc60c1f-452e-11e9-9140-
0eec59c23068_0(748c7a40db3d08c07fb4f9eba774bd5effe5f0d5090a242432a73eee66ba9e22
): Multus: Err adding pod to network "ovn-kubernetes": cannot set "ovn-kubernetes" ifname to
"eth0": no netns: failed to Statfs "/proc/33366/ns/net": no such file or directory
8m31s     Normal    Scheduled       pod/dapi-volume-test-pod                Successfully assigned
openshift-config/dapi-volume-test-pod to ip-10-0-171-202.ec2.internal
#...
```

- To view events in your project from the OpenShift Container Platform console.

1. Launch the OpenShift Container Platform console.
2. Click **Home** → **Events** and select your project.
3. Move to resource that you want to see events. For example: **Home** → **Projects** → <project-name> → <resource-name>.
 

Many objects, such as pods and deployments, have their own **Events** tab as well, which shows events related to that object.

### 8.1.3. List of events

This section describes the events of OpenShift Container Platform.

**Table 8.1. Configuration events**

Name	Description
<b>FailedValidation</b>	Failed pod configuration validation.

**Table 8.2. Container events**

Name	Description
<b>BackOff</b>	Back-off restarting failed the container.
<b>Created</b>	Container created.
<b>Failed</b>	Pull/Create/Start failed.
<b>Killing</b>	Killing the container.
<b>Started</b>	Container started.
<b>Preempting</b>	Preempting other pods.
<b>ExceededGrace Period</b>	Container runtime did not stop the pod within specified grace period.

**Table 8.3. Health events**

Name	Description
<b>Unhealthy</b>	Container is unhealthy.

**Table 8.4. Image events**

Name	Description
<b>BackOff</b>	Back off Ctr Start, image pull.
<b>ErrImageNeverPull</b>	The image's <b>NeverPull Policy</b> is violated.
<b>Failed</b>	Failed to pull the image.
<b>InspectFailed</b>	Failed to inspect the image.
<b>Pulled</b>	Successfully pulled the image or the container image is already present on the machine.
<b>Pulling</b>	Pulling the image.

Table 8.5. Image Manager events

Name	Description
<b>FreeDiskSpaceFailed</b>	Free disk space failed.
<b>InvalidDiskCapacity</b>	Invalid disk capacity.

Table 8.6. Node events

Name	Description
<b>FailedMount</b>	Volume mount failed.
<b>HostNetworkNotSupported</b>	Host network not supported.
<b>HostPortConflict</b>	Host/port conflict.
<b>KubeletSetupFailed</b>	Kubelet setup failed.
<b>NilShaper</b>	Undefined shaper.
<b>NodeNotReady</b>	Node is not ready.
<b>NodeNotSchedulable</b>	Node is not schedulable.

Name	Description
<b>NodeReady</b>	Node is ready.
<b>NodeSchedulable</b>	Node is schedulable.
<b>NodeSelectorMismatching</b>	Node selector mismatch.
<b>OutOfDisk</b>	Out of disk.
<b>Rebooted</b>	Node rebooted.
<b>Starting</b>	Starting kubelet.
<b>FailedAttachVolume</b>	Failed to attach volume.
<b>FailedDetachVolume</b>	Failed to detach volume.
<b>VolumeResizeFailed</b>	Failed to expand/reduce volume.
<b>VolumeResizeSuccessful</b>	Successfully expanded/reduced volume.
<b>FileSystemResizeFailed</b>	Failed to expand/reduce file system.
<b>FileSystemResizeSuccessful</b>	Successfully expanded/reduced file system.
<b>FailedUnMount</b>	Failed to unmount volume.
<b>FailedMapVolume</b>	Failed to map a volume.
<b>FailedUnmapDevice</b>	Failed unmaped device.
<b>AlreadyMountedVolume</b>	Volume is already mounted.
<b>SuccessfulDetachVolume</b>	Volume is successfully detached.

Name	Description
<b>SuccessfulMountVolume</b>	Volume is successfully mounted.
<b>SuccessfulUnmountVolume</b>	Volume is successfully unmounted.
<b>ContainerGCFailed</b>	Container garbage collection failed.
<b>ImageGCFailed</b>	Image garbage collection failed.
<b>FailedNodeAllocatableEnforcement</b>	Failed to enforce System Reserved Cgroup limit.
<b>NodeAllocatableEnforced</b>	Enforced System Reserved Cgroup limit.
<b>UnsupportedMountOption</b>	Unsupported mount option.
<b>SandboxChanged</b>	Pod sandbox changed.
<b>FailedCreatePodSandbox</b>	Failed to create pod sandbox.
<b>FailedPodSandboxStatus</b>	Failed pod sandbox status.

Table 8.7. Pod worker events

Name	Description
<b>FailedSync</b>	Pod sync failed.

Table 8.8. System Events

Name	Description
<b>SystemOOM</b>	There is an OOM (out of memory) situation on the cluster.

Table 8.9. Pod events

Name	Description
<b>FailedKillPod</b>	Failed to stop a pod.
<b>FailedCreatePodContainer</b>	Failed to create a pod container.
<b>Failed</b>	Failed to make pod data directories.
<b>NetworkNotReady</b>	Network is not ready.
<b>FailedCreate</b>	Error creating: <b>&lt;error-msg&gt;</b> .
<b>SuccessfulCreate</b>	Created pod: <b>&lt;pod-name&gt;</b> .
<b>FailedDelete</b>	Error deleting: <b>&lt;error-msg&gt;</b> .
<b>SuccessfulDelete</b>	Deleted pod: <b>&lt;pod-id&gt;</b> .

Table 8.10. Horizontal Pod AutoScaler events

Name	Description
SelectorRequired	Selector is required.
<b>InvalidSelector</b>	Could not convert selector into a corresponding internal selector object.
<b>FailedGetObjectMetric</b>	HPA was unable to compute the replica count.
<b>InvalidMetricSourceType</b>	Unknown metric source type.
<b>ValidMetricFound</b>	HPA was able to successfully calculate a replica count.
<b>FailedConvertHPA</b>	Failed to convert the given HPA.
<b>FailedGetScale</b>	HPA controller was unable to get the target's current scale.
<b>SucceededGetScale</b>	HPA controller was able to get the target's current scale.



Name	Description
<b>FailedComputeMetricsReplicas</b>	Failed to compute desired number of replicas based on listed metrics.
<b>FailedRescale</b>	New size: <b>&lt;size&gt;</b> ; reason: <b>&lt;msg&gt;</b> ; error: <b>&lt;error-msg&gt;</b> .
<b>SuccessfulRescale</b>	New size: <b>&lt;size&gt;</b> ; reason: <b>&lt;msg&gt;</b> .
<b>FailedUpdateStatus</b>	Failed to update status.

Table 8.11. Volume events

Name	Description
<b>FailedBinding</b>	There are no persistent volumes available and no storage class is set.
<b>VolumeMismatch</b>	Volume size or class is different from what is requested in claim.
<b>VolumeFailedRecycle</b>	Error creating recycler pod.
<b>VolumeRecycled</b>	Occurs when volume is recycled.
<b>RecyclerPod</b>	Occurs when pod is recycled.
<b>VolumeDelete</b>	Occurs when volume is deleted.
<b>VolumeFailedDelete</b>	Error when deleting the volume.
<b>ExternalProvisioning</b>	Occurs when volume for the claim is provisioned either manually or via external software.
<b>ProvisioningFailed</b>	Failed to provision volume.
<b>ProvisioningCleanupFailed</b>	Error cleaning provisioned volume.
<b>ProvisioningSucceeded</b>	Occurs when the volume is provisioned successfully.

Name	Description
<b>WaitForFirstConsumer</b>	Delay binding until pod scheduling.

Table 8.12. Lifecycle hooks

Name	Description
<b>FailedPostStartHook</b>	Handler failed for pod start.
<b>FailedPreStopHook</b>	Handler failed for pre-stop.
<b>UnfinishedPreStopHook</b>	Pre-stop hook unfinished.

Table 8.13. Deployments

Name	Description
<b>DeploymentCancellationFailed</b>	Failed to cancel deployment.
<b>DeploymentCancelled</b>	Canceled deployment.
<b>DeploymentCreated</b>	Created new replication controller.
<b>IngressIPRangeFull</b>	No available Ingress IP to allocate to service.

Table 8.14. Scheduler events

Name	Description
<b>FailedScheduling</b>	Failed to schedule pod: <b>&lt;pod-namespace&gt;/&lt;pod-name&gt;</b> . This event is raised for multiple reasons, for example: <b>AssumePodVolumes</b> failed, Binding rejected etc.
<b>Preempted</b>	By <b>&lt;preemptor-namespace&gt;/&lt;preemptor-name&gt;</b> on node <b>&lt;node-name&gt;</b> .
<b>Scheduled</b>	Successfully assigned <b>&lt;pod-name&gt;</b> to <b>&lt;node-name&gt;</b> .

Table 8.15. Daemon set events

Name	Description
<b>SelectingAll</b>	This daemon set is selecting all pods. A non-empty selector is required.
<b>FailedPlacement</b>	Failed to place pod on <b>&lt;node-name&gt;</b> .
<b>FailedDaemonPod</b>	Found failed daemon pod <b>&lt;pod-name&gt;</b> on node <b>&lt;node-name&gt;</b> , will try to kill it.

Table 8.16. LoadBalancer service events

Name	Description
<b>CreatingLoadBalancerFailed</b>	Error creating load balancer.
<b>DeletingLoadBalancer</b>	Deleting load balancer.
<b>EnsuringLoadBalancer</b>	Ensuring load balancer.
<b>EnsuredLoadBalancer</b>	Ensured load balancer.
<b>UnavailableLoadBalancer</b>	There are no available nodes for <b>LoadBalancer</b> service.
<b>LoadBalancerSourceRanges</b>	Lists the new <b>LoadBalancerSourceRanges</b> . For example, <b>&lt;old-source-range&gt;</b> → <b>&lt;new-source-range&gt;</b> .
<b>LoadbalancerIP</b>	Lists the new IP address. For example, <b>&lt;old-ip&gt;</b> → <b>&lt;new-ip&gt;</b> .
<b>ExternalIP</b>	Lists external IP address. For example, <b>Added: &lt;external-ip&gt;</b> .
<b>UID</b>	Lists the new UID. For example, <b>&lt;old-service-uid&gt;</b> → <b>&lt;new-service-uid&gt;</b> .
<b>ExternalTrafficPolicy</b>	Lists the new <b>ExternalTrafficPolicy</b> . For example, <b>&lt;old-policy&gt;</b> → <b>&lt;new-policy&gt;</b> .
<b>HealthCheckNodePort</b>	Lists the new <b>HealthCheckNodePort</b> . For example, <b>&lt;old-node-port&gt;</b> → <b>new-node-port</b> .
<b>UpdatedLoadBalancer</b>	Updated load balancer with new hosts.

Name	Description
<b>LoadBalancerUpdateFailed</b>	Error updating load balancer with new hosts.
<b>DeletingLoadBalancer</b>	Deleting load balancer.
<b>DeletingLoadBalancerFailed</b>	Error deleting load balancer.
<b>DeletedLoadBalancer</b>	Deleted load balancer.

## 8.2. ESTIMATING THE NUMBER OF PODS YOUR OPENSHIFT CONTAINER PLATFORM NODES CAN HOLD

As a cluster administrator, you can use the OpenShift Cluster Capacity Tool to view the number of pods that can be scheduled to increase the current resources before they become exhausted, and to ensure any future pods can be scheduled. This capacity comes from an individual node host in a cluster, and includes CPU, memory, disk space, and others.

### 8.2.1. Understanding the OpenShift Cluster Capacity Tool

The OpenShift Cluster Capacity Tool simulates a sequence of scheduling decisions to determine how many instances of an input pod can be scheduled on the cluster before it is exhausted of resources to provide a more accurate estimation.



#### NOTE

The remaining allocatable capacity is a rough estimation, because it does not count all of the resources being distributed among nodes. It analyzes only the remaining resources and estimates the available capacity that is still consumable in terms of a number of instances of a pod with given requirements that can be scheduled in a cluster.

Also, pods might only have scheduling support on particular sets of nodes based on its selection and affinity criteria. As a result, the estimation of which remaining pods a cluster can schedule can be difficult.

You can run the OpenShift Cluster Capacity Tool as a stand-alone utility from the command line, or as a job in a pod inside an OpenShift Container Platform cluster. Running the tool as job inside of a pod enables you to run it multiple times without intervention.

### 8.2.2. Running the OpenShift Cluster Capacity Tool on the command line

You can run the OpenShift Cluster Capacity Tool from the command line to estimate the number of pods that can be scheduled onto your cluster.

You create a sample pod spec file, which the tool uses for estimating resource usage. The pod spec specifies its resource requirements as **limits** or **requests**. The cluster capacity tool takes the pod's resource requirements into account for its estimation analysis.

## Prerequisites

1. Run the [OpenShift Cluster Capacity Tool](#), which is available as a container image from the Red Hat Ecosystem Catalog.
2. Create a sample pod spec file:
  - a. Create a YAML file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: small-pod
  labels:
    app: guestbook
    tier: frontend
spec:
  securityContext:
    runAsNonRoot: true
  seccompProfile:
    type: RuntimeDefault
  containers:
  - name: php-redis
    image: gcr.io/google-samples/gb-frontend:v4
    imagePullPolicy: Always
  resources:
    limits:
      cpu: 150m
      memory: 100Mi
    requests:
      cpu: 150m
      memory: 100Mi
  securityContext:
    allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]
```

- b. Create the cluster role:

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

For example:

```
$ oc create -f pod-spec.yaml
```

## Procedure

To use the cluster capacity tool on the command line:

1. From the terminal, log in to the Red Hat Registry:

```
$ podman login registry.redhat.io
```

2. Pull the cluster capacity tool image:

```
$ podman pull registry.redhat.io/openshift4/ose-cluster-capacity
```

3. Run the cluster capacity tool:

```
$ podman run -v $HOME/.kube:/kube:Z -v $(pwd):/cc:Z ose-cluster-capacity \
/bin/cluster-capacity --kubeconfig /kube/config --<pod_spec>.yaml /cc/<pod_spec>.yaml \
--verbose
```

where:

#### **<pod\_spec>.yaml**

Specifies the pod spec to use.

#### **verbose**

Outputs a detailed description of how many pods can be scheduled on each node in the cluster.

#### **Example output**

```
small-pod pod requirements:
```

- CPU: 150m
- Memory: 100Mi

```
The cluster can schedule 88 instance(s) of the pod small-pod.
```

```
Termination reason: Unschedulable: 0/5 nodes are available: 2 Insufficient cpu,
3 node(s) had taint {node-role.kubernetes.io/master: }, that the pod didn't
tolerate.
```

```
Pod distribution among nodes:
```

- ```
small-pod
- 192.168.124.214: 45 instance(s)
- 192.168.124.120: 43 instance(s)
```

In the above example, the number of estimated pods that can be scheduled onto the cluster is 88.

### **8.2.3. Running the OpenShift Cluster Capacity Tool as a job inside a pod**

Running the OpenShift Cluster Capacity Tool as a job inside of a pod allows you to run the tool multiple times without needing user intervention. You run the OpenShift Cluster Capacity Tool as a job by using a **ConfigMap** object.

#### **Prerequisites**

Download and install [OpenShift Cluster Capacity Tool](#).

#### **Procedure**

To run the cluster capacity tool:

## 1. Create the cluster role:

## a. Create a YAML file similar to the following:

```
kind: ClusterRole
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: cluster-capacity-role
rules:
- apiGroups: ["" ]
  resources: ["pods", "nodes", "persistentvolumeclaims", "persistentvolumes", "services",
"replicationcontrollers"]
  verbs: ["get", "watch", "list"]
- apiGroups: ["apps"]
  resources: ["replicasets", "statefulsets"]
  verbs: ["get", "watch", "list"]
- apiGroups: ["policy"]
  resources: ["poddisruptionbudgets"]
  verbs: ["get", "watch", "list"]
- apiGroups: ["storage.k8s.io"]
  resources: ["storageclasses"]
  verbs: ["get", "watch", "list"]
```

## b. Create the cluster role by running the following command:

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

For example:

```
$ oc create sa cluster-capacity-sa
```

## 2. Create the service account:

```
$ oc create sa cluster-capacity-sa -n default
```

## 3. Add the role to the service account:

```
$ oc adm policy add-cluster-role-to-user cluster-capacity-role \
system:serviceaccount:<namespace>:cluster-capacity-sa
```

where:

**<namespace>**

Specifies the namespace where the pod is located.

## 4. Define and create the pod spec:

## a. Create a YAML file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: small-pod
labels:
```

```

    app: guestbook
    tier: frontend
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: php-redis
    image: gcr.io/google-samples/gb-frontend:v4
    imagePullPolicy: Always
  resources:
    limits:
      cpu: 150m
      memory: 100Mi
    requests:
      cpu: 150m
      memory: 100Mi
  securityContext:
    allowPrivilegeEscalation: false
  capabilities:
    drop: [ALL]

```

- b. Create the pod by running the following command:

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

For example:

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

5. Create a config map object by running the following command:

```
$ oc create configmap cluster-capacity-configmap \
  --from-file=pod.yaml=pod.yaml
```

The cluster capacity analysis is mounted in a volume using a config map object named **cluster-capacity-configmap** to mount the input pod spec file **pod.yaml** into a volume **test-volume** at the path **/test-pod**.

6. Create the job using the below example of a job specification file:

- a. Create a YAML file similar to the following:

```

apiVersion: batch/v1
kind: Job
metadata:
  name: cluster-capacity-job
spec:
  parallelism: 1
  completions: 1
  template:
    metadata:
      name: cluster-capacity-pod
    spec:

```



```

containers:
- name: cluster-capacity
  image: openshift/origin-cluster-capacity
  imagePullPolicy: "Always"
  volumeMounts:
  - mountPath: /test-pod
    name: test-volume
  env:
  - name: CC_INCLUSTER 1
    value: "true"
  command:
  - "/bin/sh"
  - "-ec"
  - |
    /bin/cluster-capacity --podspec=/test-pod/pod.yaml --verbose
  restartPolicy: "Never"
serviceAccountName: cluster-capacity-sa
volumes:
- name: test-volume
  configMap:
    name: cluster-capacity-configmap

```

- 1** A required environment variable letting the cluster capacity tool know that it is running inside a cluster as a pod. The **pod.yaml** key of the **ConfigMap** object is the same as the **Pod** spec file name, though it is not required. By doing this, the input pod spec file can be accessed inside the pod as **/test-pod/pod.yaml**.

- b. Run the cluster capacity image as a job in a pod by running the following command:

```
$ oc create -f cluster-capacity-job.yaml
```

## Verification

1. Check the job logs to find the number of pods that can be scheduled in the cluster:

```
$ oc logs jobs/cluster-capacity-job
```

## Example output

```

small-pod pod requirements:
- CPU: 150m
- Memory: 100Mi

```

The cluster can schedule 52 instance(s) of the pod small-pod.

Termination reason: Unschedulable: No nodes are available that match all of the following predicates:: Insufficient cpu (2).

```

Pod distribution among nodes:
small-pod
- 192.168.124.214: 26 instance(s)
- 192.168.124.120: 26 instance(s)

```

## 8.3. RESTRICT RESOURCE CONSUMPTION WITH LIMIT RANGES

By default, containers run with unbounded compute resources on an OpenShift Container Platform cluster. With limit ranges, you can restrict resource consumption for specific objects in a project:

- pods and containers: You can set minimum and maximum requirements for CPU and memory for pods and their containers.
- Image streams: You can set limits on the number of images and tags in an **ImageStream** object.
- Images: You can limit the size of images that can be pushed to an internal registry.
- Persistent volume claims (PVC): You can restrict the size of the PVCs that can be requested.

If a pod does not meet the constraints imposed by the limit range, the pod cannot be created in the namespace.

### 8.3.1. About limit ranges

A limit range, defined by a **LimitRange** object, restricts resource consumption in a project. In the project you can set specific resource limits for a pod, container, image, image stream, or persistent volume claim (PVC).

All requests to create and modify resources are evaluated against each **LimitRange** object in the project. If the resource violates any of the enumerated constraints, the resource is rejected.

The following shows a limit range object for all components: pod, container, image, image stream, or PVC. You can configure limits for any or all of these components in the same object. You create a different limit range object for each project where you want to control resources.

#### Sample limit range object for a container

```
apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits"
spec:
  limits:
  - type: "Container"
    max:
      cpu: "2"
      memory: "1Gi"
    min:
      cpu: "100m"
      memory: "4Mi"
    default:
      cpu: "300m"
      memory: "200Mi"
    defaultRequest:
      cpu: "200m"
      memory: "100Mi"
    maxLimitRequestRatio:
      cpu: "10"
```

#### 8.3.1.1. About component limits

The following examples show limit range parameters for each component. The examples are broken out for clarity. You can create a single **LimitRange** object for any or all components as necessary.

### 8.3.1.1.1. Container limits

A limit range allows you to specify the minimum and maximum CPU and memory that each container in a pod can request for a specific project. If a container is created in the project, the container CPU and memory requests in the **Pod** spec must comply with the values set in the **LimitRange** object. If not, the pod does not get created.

- The container CPU or memory request and limit must be greater than or equal to the **min** resource constraint for containers that are specified in the **LimitRange** object.
- The container CPU or memory request and limit must be less than or equal to the **max** resource constraint for containers that are specified in the **LimitRange** object.  
If the **LimitRange** object defines a **max** CPU, you do not need to define a CPU **request** value in the **Pod** spec. But you must specify a CPU **limit** value that satisfies the maximum CPU constraint specified in the limit range.
- The ratio of the container limits to requests must be less than or equal to the **maxLimitRequestRatio** value for containers that is specified in the **LimitRange** object.  
If the **LimitRange** object defines a **maxLimitRequestRatio** constraint, any new containers must have both a **request** and a **limit** value. OpenShift Container Platform calculates the limit-to-request ratio by dividing the **limit** by the **request**. This value should be a non-negative integer greater than 1.

For example, if a container has **cpu: 500** in the **limit** value, and **cpu: 100** in the **request** value, the limit-to-request ratio for **cpu** is **5**. This ratio must be less than or equal to the **maxLimitRequestRatio**.

If the **Pod** spec does not specify a container resource memory or limit, the **default** or **defaultRequest** CPU and memory values for containers specified in the limit range object are assigned to the container.

### Container LimitRange object definition

```
apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits" 1
spec:
  limits:
  - type: "Container"
    max:
      cpu: "2" 2
      memory: "1Gi" 3
    min:
      cpu: "100m" 4
      memory: "4Mi" 5
    default:
      cpu: "300m" 6
      memory: "200Mi" 7
    defaultRequest:
      cpu: "200m" 8
```

```
memory: "100Mi" 9
maxLimitRequestRatio:
cpu: "10" 10
```

- 1 The name of the LimitRange object.
- 2 The maximum amount of CPU that a single container in a pod can request.
- 3 The maximum amount of memory that a single container in a pod can request.
- 4 The minimum amount of CPU that a single container in a pod can request.
- 5 The minimum amount of memory that a single container in a pod can request.
- 6 The default amount of CPU that a container can use if not specified in the **Pod** spec.
- 7 The default amount of memory that a container can use if not specified in the **Pod** spec.
- 8 The default amount of CPU that a container can request if not specified in the **Pod** spec.
- 9 The default amount of memory that a container can request if not specified in the **Pod** spec.
- 10 The maximum limit-to-request ratio for a container.

#### 8.3.1.1.2. Pod limits

A limit range allows you to specify the minimum and maximum CPU and memory limits for all containers across a pod in a given project. To create a container in the project, the container CPU and memory requests in the **Pod** spec must comply with the values set in the **LimitRange** object. If not, the pod does not get created.

If the **Pod** spec does not specify a container resource memory or limit, the **default** or **defaultRequest** CPU and memory values for containers specified in the limit range object are assigned to the container.

Across all containers in a pod, the following must hold true:

- The container CPU or memory request and limit must be greater than or equal to the **min** resource constraints for pods that are specified in the **LimitRange** object.
- The container CPU or memory request and limit must be less than or equal to the **max** resource constraints for pods that are specified in the **LimitRange** object.
- The ratio of the container limits to requests must be less than or equal to the **maxLimitRequestRatio** constraint specified in the **LimitRange** object.

#### Pod LimitRange object definition

```
apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits" 1
spec:
  limits:
    - type: "Pod"
      max:
```

```

cpu: "2" 2
memory: "1Gi" 3
min:
  cpu: "200m" 4
  memory: "6Mi" 5
maxLimitRequestRatio:
  cpu: "10" 6

```

- 1 The name of the limit range object.
- 2 The maximum amount of CPU that a pod can request across all containers.
- 3 The maximum amount of memory that a pod can request across all containers.
- 4 The minimum amount of CPU that a pod can request across all containers.
- 5 The minimum amount of memory that a pod can request across all containers.
- 6 The maximum limit-to-request ratio for a container.

### 8.3.1.1.3. Image limits

A **LimitRange** object allows you to specify the maximum size of an image that can be pushed to an OpenShift image registry.

When pushing images to an OpenShift image registry, the following must hold true:

- The size of the image must be less than or equal to the **max** size for images that is specified in the **LimitRange** object.

#### Image **LimitRange** object definition

```

apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits" 1
spec:
  limits:
    - type: openshift.io/Image
      max:
        storage: 1Gi 2

```

- 1 The name of the **LimitRange** object.
- 2 The maximum size of an image that can be pushed to an OpenShift image registry.



#### NOTE

To prevent blobs that exceed the limit from being uploaded to the registry, the registry must be configured to enforce quotas.



## WARNING

The image size is not always available in the manifest of an uploaded image. This is especially the case for images built with Docker 1.10 or higher and pushed to a v2 registry. If such an image is pulled with an older Docker daemon, the image manifest is converted by the registry to schema v1 lacking all the size information. No storage limit set on images prevent it from being uploaded.

[The issue](#) is being addressed.

### 8.3.1.1.4. Image stream limits

A **LimitRange** object allows you to specify limits for image streams.

For each image stream, the following must hold true:

- The number of image tags in an **ImageStream** specification must be less than or equal to the **openshift.io/image-tags** constraint in the **LimitRange** object.
- The number of unique references to images in an **ImageStream** specification must be less than or equal to the **openshift.io/images** constraint in the limit range object.

### Imagestream **LimitRange** object definition

```
apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits" 1
spec:
  limits:
    - type: openshift.io/ImageStream
      max:
        openshift.io/image-tags: 20 2
        openshift.io/images: 30 3
```

- 1 The name of the **LimitRange** object.
- 2 The maximum number of unique image tags in the **imagestream.spec.tags** parameter in imagestream spec.
- 3 The maximum number of unique image references in the **imagestream.status.tags** parameter in the **imagestream** spec.

The **openshift.io/image-tags** resource represents unique image references. Possible references are an **ImageStreamTag**, an **ImageStreamImage** and a **DockerImage**. Tags can be created using the **oc tag** and **oc import-image** commands. No distinction is made between internal and external references. However, each unique reference tagged in an **ImageStream** specification is counted just once. It does not restrict pushes to an internal container image registry in any way, but is useful for tag restriction.

The **openshift.io/images** resource represents unique image names recorded in image stream status. It allows for restriction of a number of images that can be pushed to the OpenShift image registry. Internal and external references are not distinguished.

### 8.3.1.1.5. Persistent volume claim limits

A **LimitRange** object allows you to restrict the storage requested in a persistent volume claim (PVC).

Across all persistent volume claims in a project, the following must hold true:

- The resource request in a persistent volume claim (PVC) must be greater than or equal the **min** constraint for PVCs that is specified in the **LimitRange** object.
- The resource request in a persistent volume claim (PVC) must be less than or equal the **max** constraint for PVCs that is specified in the **LimitRange** object.

### PVC LimitRange object definition

```
apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits" 1
spec:
  limits:
    - type: "PersistentVolumeClaim"
      min:
        storage: "2Gi" 2
      max:
        storage: "50Gi" 3
```

- 1 The name of the **LimitRange** object.
- 2 The minimum amount of storage that can be requested in a persistent volume claim.
- 3 The maximum amount of storage that can be requested in a persistent volume claim.

### 8.3.2. Creating a Limit Range

To apply a limit range to a project:

1. Create a **LimitRange** object with your required specifications:

```
apiVersion: "v1"
kind: "LimitRange"
metadata:
  name: "resource-limits" 1
spec:
  limits:
    - type: "Pod" 2
      max:
        cpu: "2"
        memory: "1Gi"
      min:
        cpu: "200m"
```

```

    memory: "6Mi"
  - type: "Container" 3
    max:
      cpu: "2"
      memory: "1Gi"
    min:
      cpu: "100m"
      memory: "4Mi"
    default: 4
      cpu: "300m"
      memory: "200Mi"
    defaultRequest: 5
      cpu: "200m"
      memory: "100Mi"
    maxLimitRequestRatio: 6
      cpu: "10"
  - type: openshift.io/Image 7
    max:
      storage: 1Gi
  - type: openshift.io/ImageStream 8
    max:
      openshift.io/image-tags: 20
      openshift.io/images: 30
  - type: "PersistentVolumeClaim" 9
    min:
      storage: "2Gi"
    max:
      storage: "50Gi"

```

- 1 Specify a name for the **LimitRange** object.
- 2 To set limits for a pod, specify the minimum and maximum CPU and memory requests as needed.
- 3 To set limits for a container, specify the minimum and maximum CPU and memory requests as needed.
- 4 Optional. For a container, specify the default amount of CPU or memory that a container can use, if not specified in the **Pod** spec.
- 5 Optional. For a container, specify the default amount of CPU or memory that a container can request, if not specified in the **Pod** spec.
- 6 Optional. For a container, specify the maximum limit-to-request ratio that can be specified in the **Pod** spec.
- 7 To set limits for an Image object, set the maximum size of an image that can be pushed to an OpenShift image registry.
- 8 To set limits for an image stream, set the maximum number of image tags and references that can be in the **ImageStream** object file, as needed.
- 9 To set limits for a persistent volume claim, set the minimum and maximum amount of storage that can be requested.



2. Create the object:

```
$ oc create -f <limit_range_file> -n <project> 1
```

- 1 Specify the name of the YAML file you created and the project where you want the limits to apply.

### 8.3.3. Viewing a limit

You can view any limits defined in a project by navigating in the web console to the project's **Quota** page.

You can also use the CLI to view limit range details:

1. Get the list of **LimitRange** object defined in the project. For example, for a project called **demoproject**:

```
$ oc get limits -n demoproject
```

```
NAME          CREATED AT
resource-limits 2020-07-15T17:14:23Z
```

2. Describe the **LimitRange** object you are interested in, for example the **resource-limits** limit range:

```
$ oc describe limits resource-limits -n demoproject
```

```
Name:                resource-limits
Namespace:           demoproject
Type:                Resource
Limit/Request Ratio
-----
Pod                  cpu                200m  2    -    -    -
Pod                  memory             6Mi   1Gi  -    -    -
Container            cpu                100m  2    200m 300m  10
Container            memory             4Mi   1Gi  100Mi 200Mi -
openshift.io/Image  storage            -     1Gi  -    -    -
openshift.io/ImageStream  openshift.io/image -    12  -    -    -
openshift.io/ImageStream  openshift.io/image-tags -   10  -    -    -
PersistentVolumeClaim  storage            -     50Gi -    -    -
```

### 8.3.4. Deleting a Limit Range

To remove any active **LimitRange** object to no longer enforce the limits in a project:

- Run the following command:

```
$ oc delete limits <limit_name>
```

## 8.4. CONFIGURING CLUSTER MEMORY TO MEET CONTAINER MEMORY AND RISK REQUIREMENTS

As a cluster administrator, you can help your clusters operate efficiently through managing application memory by:

- Determining the memory and risk requirements of a containerized application component and configuring the container memory parameters to suit those requirements.
- Configuring containerized application runtimes (for example, OpenJDK) to adhere optimally to the configured container memory parameters.
- Diagnosing and resolving memory-related error conditions associated with running in a container.

### 8.4.1. Understanding managing application memory

It is recommended to fully read the overview of how OpenShift Container Platform manages Compute Resources before proceeding.

For each kind of resource (memory, CPU, storage), OpenShift Container Platform allows optional **request** and **limit** values to be placed on each container in a pod.

Note the following about memory requests and memory limits:

- **Memory request**
  - The memory request value, if specified, influences the OpenShift Container Platform scheduler. The scheduler considers the memory request when scheduling a container to a node, then fences off the requested memory on the chosen node for the use of the container.
  - If a node's memory is exhausted, OpenShift Container Platform prioritizes evicting its containers whose memory usage most exceeds their memory request. In serious cases of memory exhaustion, the node OOM killer may select and kill a process in a container based on a similar metric.
  - The cluster administrator can assign quota or assign default values for the memory request value.
  - The cluster administrator can override the memory request values that a developer specifies, to manage cluster overcommit.
- **Memory limit**
  - The memory limit value, if specified, provides a hard limit on the memory that can be allocated across all the processes in a container.
  - If the memory allocated by all of the processes in a container exceeds the memory limit, the node Out of Memory (OOM) killer will immediately select and kill a process in the container.
  - If both memory request and limit are specified, the memory limit value must be greater than or equal to the memory request.
  - The cluster administrator can assign quota or assign default values for the memory limit value.
  - The minimum memory limit is 12 MB. If a container fails to start due to a **Cannot allocate memory** pod event, the memory limit is too low. Either increase or remove the memory limit. Removing the limit allows pods to consume unbounded node resources.

### 8.4.1.1. Managing application memory strategy

The steps for sizing application memory on OpenShift Container Platform are as follows:

1. **Determine expected container memory usage**

Determine expected mean and peak container memory usage, empirically if necessary (for example, by separate load testing). Remember to consider all the processes that may potentially run in parallel in the container: for example, does the main application spawn any ancillary scripts?

2. **Determine risk appetite**

Determine risk appetite for eviction. If the risk appetite is low, the container should request memory according to the expected peak usage plus a percentage safety margin. If the risk appetite is higher, it may be more appropriate to request memory according to the expected mean usage.

3. **Set container memory request**

Set container memory request based on the above. The more accurately the request represents the application memory usage, the better. If the request is too high, cluster and quota usage will be inefficient. If the request is too low, the chances of application eviction increase.

4. **Set container memory limit, if required**

Set container memory limit, if required. Setting a limit has the effect of immediately killing a container process if the combined memory usage of all processes in the container exceeds the limit, and is therefore a mixed blessing. On the one hand, it may make unanticipated excess memory usage obvious early ("fail fast"); on the other hand it also terminates processes abruptly.

Note that some OpenShift Container Platform clusters may require a limit value to be set; some may override the request based on the limit; and some application images rely on a limit value being set as this is easier to detect than a request value.

If the memory limit is set, it should not be set to less than the expected peak container memory usage plus a percentage safety margin.

5. **Ensure application is tuned**

Ensure application is tuned with respect to configured request and limit values, if appropriate. This step is particularly relevant to applications which pool memory, such as the JVM. The rest of this page discusses this.

#### Additional resources

- [Understanding compute resources and containers](#)

### 8.4.2. Understanding OpenJDK settings for OpenShift Container Platform

The default OpenJDK settings do not work well with containerized environments. As a result, some additional Java memory settings must always be provided whenever running the OpenJDK in a container.

The JVM memory layout is complex, version dependent, and describing it in detail is beyond the scope of this documentation. However, as a starting point for running OpenJDK in a container, at least the following three memory-related tasks are key:

1. Overriding the JVM maximum heap size.

2. Encouraging the JVM to release unused memory to the operating system, if appropriate.
3. Ensuring all JVM processes within a container are appropriately configured.

Optimally tuning JVM workloads for running in a container is beyond the scope of this documentation, and may involve setting multiple additional JVM options.

#### 8.4.2.1. Understanding how to override the JVM maximum heap size

For many Java workloads, the JVM heap is the largest single consumer of memory. Currently, the OpenJDK defaults to allowing up to 1/4 (1/**-XX:MaxRAMFraction**) of the compute node's memory to be used for the heap, regardless of whether the OpenJDK is running in a container or not. It is therefore **essential** to override this behavior, especially if a container memory limit is also set.

There are at least two ways the above can be achieved:

- If the container memory limit is set and the experimental options are supported by the JVM, set **-XX:+UnlockExperimentalVMOptions -XX:+UseCGroupMemoryLimitForHeap**.



#### NOTE

The **UseCGroupMemoryLimitForHeap** option has been removed in JDK 11. Use **-XX:+UseContainerSupport** instead.

This sets **-XX:MaxRAM** to the container memory limit, and the maximum heap size (**-XX:MaxHeapSize** / **-Xmx**) to 1/ **-XX:MaxRAMFraction** (1/4 by default).

- Directly override one of **-XX:MaxRAM**, **-XX:MaxHeapSize** or **-Xmx**.  
This option involves hard-coding a value, but has the advantage of allowing a safety margin to be calculated.

#### 8.4.2.2. Understanding how to encourage the JVM to release unused memory to the operating system

By default, the OpenJDK does not aggressively return unused memory to the operating system. This may be appropriate for many containerized Java workloads, but notable exceptions include workloads where additional active processes co-exist with a JVM within a container, whether those additional processes are native, additional JVMs, or a combination of the two.

Java-based agents can use the following JVM arguments to encourage the JVM to release unused memory to the operating system:

```
-XX:+UseParallelGC
-XX:MinHeapFreeRatio=5 -XX:MaxHeapFreeRatio=10 -XX:GCTimeRatio=4
-XX:AdaptiveSizePolicyWeight=90.
```

These arguments are intended to return heap memory to the operating system whenever allocated memory exceeds 110% of in-use memory (**-XX:MaxHeapFreeRatio**), spending up to 20% of CPU time in the garbage collector (**-XX:GCTimeRatio**). At no time will the application heap allocation be less than the initial heap allocation (overridden by **-XX:InitialHeapSize** / **-Xms**). Detailed additional information is available [Tuning Java's footprint in OpenShift \(Part 1\)](#) , [Tuning Java's footprint in OpenShift \(Part 2\)](#) , and at [OpenJDK and Containers](#).

### 8.4.2.3. Understanding how to ensure all JVM processes within a container are appropriately configured

In the case that multiple JVMs run in the same container, it is essential to ensure that they are all configured appropriately. For many workloads it will be necessary to grant each JVM a percentage memory budget, leaving a perhaps substantial additional safety margin.

Many Java tools use different environment variables (**JAVA\_OPTS**, **GRADLE\_OPTS**, and so on) to configure their JVMs and it can be challenging to ensure that the right settings are being passed to the right JVM.

The **JAVA\_TOOL\_OPTIONS** environment variable is always respected by the OpenJDK, and values specified in **JAVA\_TOOL\_OPTIONS** will be overridden by other options specified on the JVM command line. By default, to ensure that these options are used by default for all JVM workloads run in the Java-based agent image, the OpenShift Container Platform Jenkins Maven agent image sets:

```
JAVA_TOOL_OPTIONS="-XX:+UnlockExperimentalVMOptions
-XX:+UseCGroupMemoryLimitForHeap -Dsun.zip.disableMemoryMapping=true"
```



#### NOTE

The **UseCGroupMemoryLimitForHeap** option has been removed in JDK 11. Use **-XX:+UseContainerSupport** instead.

This does not guarantee that additional options are not required, but is intended to be a helpful starting point.

### 8.4.3. Finding the memory request and limit from within a pod

An application wishing to dynamically discover its memory request and limit from within a pod should use the Downward API.

#### Procedure

1. Configure the pod to add the **MEMORY\_REQUEST** and **MEMORY\_LIMIT** stanzas:
  - a. Create a YAML file similar to the following:

```
apiVersion: v1
kind: Pod
metadata:
  name: test
spec:
  securityContext:
    runAsNonRoot: true
    seccompProfile:
      type: RuntimeDefault
  containers:
  - name: test
    image: fedora:latest
    command:
    - sleep
    - "3600"
    env:
    - name: MEMORY_REQUEST 1
```

```

valueFrom:
  resourceFieldRef:
    containerName: test
    resource: requests.memory
- name: MEMORY_LIMIT 2
  valueFrom:
    resourceFieldRef:
      containerName: test
      resource: limits.memory
resources:
  requests:
    memory: 384Mi
  limits:
    memory: 512Mi
securityContext:
  allowPrivilegeEscalation: false
capabilities:
  drop: [ALL]

```

- 1** Add this stanza to discover the application memory request value.
- 2** Add this stanza to discover the application memory limit value.

b. Create the pod by running the following command:

```
$ oc create -f <file-name>.yaml
```

### Verification

1. Access the pod using a remote shell:

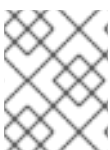
```
$ oc rsh test
```

2. Check that the requested values were applied:

```
$ env | grep MEMORY | sort
```

### Example output

```
MEMORY_LIMIT=536870912
MEMORY_REQUEST=402653184
```



#### NOTE

The memory limit value can also be read from inside the container by the `/sys/fs/cgroup/memory/memory.limit_in_bytes` file.

### 8.4.4. Understanding OOM kill policy

OpenShift Container Platform can kill a process in a container if the total memory usage of all the processes in the container exceeds the memory limit, or in serious cases of node memory exhaustion.

When a process is Out of Memory (OOM) killed, this might result in the container exiting immediately. If the container PID 1 process receives the **SIGKILL**, the container will exit immediately. Otherwise, the container behavior is dependent on the behavior of the other processes.

For example, a container process exited with code 137, indicating it received a SIGKILL signal.

If the container does not exit immediately, an OOM kill is detectable as follows:

1. Access the pod using a remote shell:

```
# oc rsh test
```

2. Run the following command to see the current OOM kill count in **/sys/fs/cgroup/memory/memory.oom\_control**:

```
$ grep '^oom_kill' /sys/fs/cgroup/memory/memory.oom_control
```

#### Example output

```
oom_kill 0
```

3. Run the following command to provoke an OOM kill:

```
$ sed -e " </dev/zero
```

#### Example output

```
Killed
```

4. Run the following command to view the exit status of the **sed** command:

```
$ echo $?
```

#### Example output

```
137
```

The **137** code indicates the container process exited with code 137, indicating it received a SIGKILL signal.

5. Run the following command to see that the OOM kill counter in **/sys/fs/cgroup/memory/memory.oom\_control** incremented:

```
$ grep '^oom_kill' /sys/fs/cgroup/memory/memory.oom_control
```

#### Example output

```
oom_kill 1
```

If one or more processes in a pod are OOM killed, when the pod subsequently exits, whether immediately or not, it will have phase **Failed** and reason **OOMKilled**. An OOM-killed pod might be restarted depending on the value of **restartPolicy**. If not restarted, controllers such as the

replication controller will notice the pod's failed status and create a new pod to replace the old one.

Use the following command to get the pod status:

```
$ oc get pod test
```

### Example output

```
NAME    READY   STATUS    RESTARTS   AGE
test    0/1     OOMKilled 0           1m
```

- If the pod has not restarted, run the following command to view the pod:

```
$ oc get pod test -o yaml
```

### Example output

```
...
status:
  containerStatuses:
  - name: test
    ready: false
    restartCount: 0
  state:
    terminated:
      exitCode: 137
      reason: OOMKilled
    phase: Failed
```

- If restarted, run the following command to view the pod:

```
$ oc get pod test -o yaml
```

### Example output

```
...
status:
  containerStatuses:
  - name: test
    ready: true
    restartCount: 1
  lastState:
    terminated:
      exitCode: 137
      reason: OOMKilled
  state:
    running:
    phase: Running
```

## 8.4.5. Understanding pod eviction



OpenShift Container Platform may evict a pod from its node when the node's memory is exhausted. Depending on the extent of memory exhaustion, the eviction may or may not be graceful. Graceful eviction implies the main process (PID 1) of each container receiving a SIGTERM signal, then some time later a SIGKILL signal if the process has not exited already. Non-graceful eviction implies the main process of each container immediately receiving a SIGKILL signal.

An evicted pod has phase **Failed** and reason **Evicted**. It will not be restarted, regardless of the value of **restartPolicy**. However, controllers such as the replication controller will notice the pod's failed status and create a new pod to replace the old one.

```
$ oc get pod test
```

### Example output

```
NAME    READY   STATUS    RESTARTS  AGE
test    0/1     Evicted  0          1m
```

```
$ oc get pod test -o yaml
```

### Example output

```
...
status:
  message: 'Pod The node was low on resource: [MemoryPressure].'
```

```
  phase: Failed
  reason: Evicted
```

## 8.5. CONFIGURING YOUR CLUSTER TO PLACE PODS ON OVERCOMMITTED NODES

In an *overcommitted* state, the sum of the container compute resource requests and limits exceeds the resources available on the system. For example, you might want to use overcommitment in development environments where a trade-off of guaranteed performance for capacity is acceptable.

Containers can specify compute resource requests and limits. Requests are used for scheduling your container and provide a minimum service guarantee. Limits constrain the amount of compute resource that can be consumed on your node.

The scheduler attempts to optimize the compute resource use across all nodes in your cluster. It places pods onto specific nodes, taking the pods' compute resource requests and nodes' available capacity into consideration.

OpenShift Container Platform administrators can control the level of overcommit and manage container density on nodes. You can configure cluster-level overcommit using the [ClusterResourceOverride Operator](#) to override the ratio between requests and limits set on developer containers. In conjunction with [node overcommit](#) and [project memory and CPU limits and defaults](#), you can adjust the resource limit and request to achieve the desired level of overcommit.



### NOTE

In OpenShift Container Platform, you must enable cluster-level overcommit. Node overcommitment is enabled by default. See [Disabling overcommitment for a node](#).

### 8.5.1. Resource requests and overcommitment

For each compute resource, a container may specify a resource request and limit. Scheduling decisions are made based on the request to ensure that a node has enough capacity available to meet the requested value. If a container specifies limits, but omits requests, the requests are defaulted to the limits. A container is not able to exceed the specified limit on the node.

The enforcement of limits is dependent upon the compute resource type. If a container makes no request or limit, the container is scheduled to a node with no resource guarantees. In practice, the container is able to consume as much of the specified resource as is available with the lowest local priority. In low resource situations, containers that specify no resource requests are given the lowest quality of service.

Scheduling is based on resources requested, while quota and hard limits refer to resource limits, which can be set higher than requested resources. The difference between request and limit determines the level of overcommit; for instance, if a container is given a memory request of 1Gi and a memory limit of 2Gi, it is scheduled based on the 1Gi request being available on the node, but could use up to 2Gi; so it is 200% overcommitted.

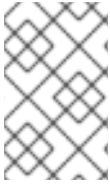
### 8.5.2. Cluster-level overcommit using the Cluster Resource Override Operator

The Cluster Resource Override Operator is an admission webhook that allows you to control the level of overcommit and manage container density across all the nodes in your cluster. The Operator controls how nodes in specific projects can exceed defined memory and CPU limits.

You must install the Cluster Resource Override Operator using the OpenShift Container Platform console or CLI as shown in the following sections. During the installation, you create a **ClusterResourceOverride** custom resource (CR), where you set the level of overcommit, as shown in the following example:

```
apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  name: cluster 1
spec:
  podResourceOverride:
    spec:
      memoryRequestToLimitPercent: 50 2
      cpuRequestToLimitPercent: 25 3
      limitCPUMemoryPercent: 200 4
# ...
```

- 1** The name must be **cluster**.
- 2** Optional. If a container memory limit has been specified or defaulted, the memory request is overridden to this percentage of the limit, between 1-100. The default is 50.
- 3** Optional. If a container CPU limit has been specified or defaulted, the CPU request is overridden to this percentage of the limit, between 1-100. The default is 25.
- 4** Optional. If a container memory limit has been specified or defaulted, the CPU limit is overridden to a percentage of the memory limit, if specified. Scaling 1Gi of RAM at 100 percent is equal to 1 CPU core. This is processed prior to overriding the CPU request (if configured). The default is 200.



## NOTE

The Cluster Resource Override Operator overrides have no effect if limits have not been set on containers. Create a **LimitRange** object with default limits per individual project or configure limits in **Pod** specs for the overrides to apply.

When configured, overrides can be enabled per-project by applying the following label to the Namespace object for each project:

```
apiVersion: v1
kind: Namespace
metadata:

# ...

labels:
  clusterresourceoverrides.admission.autoscaling.openshift.io/enabled: "true"

# ...
```

The Operator watches for the **ClusterResourceOverride** CR and ensures that the **ClusterResourceOverride** admission webhook is installed into the same namespace as the operator.

### 8.5.2.1. Installing the Cluster Resource Override Operator using the web console

You can use the OpenShift Container Platform CLI to install the Cluster Resource Override Operator to help control overcommit in your cluster.

By default, the installation process creates a Cluster Resource Override Operator pod on a worker node in the **clusterresourceoverride-operator** namespace. You can move this pod to another node, such as an infrastructure node, as needed. Infrastructure nodes are not counted toward the total number of subscriptions that are required to run the environment. For more information, see "Moving the Cluster Resource Override Operator pods".

#### Prerequisites

- The Cluster Resource Override Operator has no effect if limits have not been set on containers. You must specify default limits for a project using a **LimitRange** object or configure limits in **Pod** specs for the overrides to apply.

#### Procedure

To install the Cluster Resource Override Operator using the OpenShift Container Platform web console:

1. In the OpenShift Container Platform web console, navigate to **Home → Projects**
  - a. Click **Create Project**.
  - b. Specify **clusterresourceoverride-operator** as the name of the project.
  - c. Click **Create**.
2. Navigate to **Operators → OperatorHub**.
  - a. Choose **ClusterResourceOverride Operator** from the list of available Operators and click **Install**.

- b. On the **Install Operator** page, make sure **A specific Namespace on the cluster** is selected for **Installation Mode**.
  - c. Make sure **clusterresourceoverride-operator** is selected for **Installed Namespace**.
  - d. Select an **Update Channel** and **Approval Strategy**.
  - e. Click **Install**.
3. On the **Installed Operators** page, click **ClusterResourceOverride**.
    - a. On the **ClusterResourceOverride Operator** details page, click **Create ClusterResourceOverride**.
    - b. On the **Create ClusterResourceOverride** page, click **YAML view** and edit the YAML template to set the overcommit values as needed:

```

apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  name: cluster 1
spec:
  podResourceOverride:
    spec:
      memoryRequestToLimitPercent: 50 2
      cpuRequestToLimitPercent: 25 3
      limitCPUMemoryPercent: 200 4

```

- 1** The name must be **cluster**.
- 2** Optional: Specify the percentage to override the container memory limit, if used, between 1-100. The default is **50**.
- 3** Optional: Specify the percentage to override the container CPU limit, if used, between 1-100. The default is **25**.
- 4** Optional: Specify the percentage to override the container memory limit, if used. Scaling 1 Gi of RAM at 100 percent is equal to 1 CPU core. This is processed before overriding the CPU request, if configured. The default is **200**.

- c. Click **Create**.
4. Check the current state of the admission webhook by checking the status of the cluster custom resource:
    - a. On the **ClusterResourceOverride Operator** page, click **cluster**.
    - b. On the **ClusterResourceOverride Details** page, click **YAML**. The **mutatingWebhookConfigurationRef** section appears when the webhook is called.

```

apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  annotations:
    kubectrl.kubernetes.io/last-applied-configuration: |

```

```

{"apiVersion":"operator.autoscaling.openshift.io/v1","kind":"ClusterResourceOverride","met
adata":{"annotations":{},"name":"cluster"},"spec":{"podResourceOverride":{"spec":
{"cpuRequestToLimitPercent":25,"limitCPUMemoryPercent":200,"memoryRequestToLi
mitPercent":50}}}}
  creationTimestamp: "2019-12-18T22:35:02Z"
  generation: 1
  name: cluster
  resourceVersion: "127622"
  selfLink: /apis/operator.autoscaling.openshift.io/v1/clusterresourceoverrides/cluster
  uid: 978fc959-1717-4bd1-97d0-ae00ee111e8d
spec:
  podResourceOverride:
    spec:
      cpuRequestToLimitPercent: 25
      limitCPUMemoryPercent: 200
      memoryRequestToLimitPercent: 50
status:

# ...

mutatingWebhookConfigurationRef: 1
  apiVersion: admissionregistration.k8s.io/v1
  kind: MutatingWebhookConfiguration
  name: clusterresourceoverrides.admission.autoscaling.openshift.io
  resourceVersion: "127621"
  uid: 98b3b8ae-d5ce-462b-8ab5-a729ea8f38f3

# ...

```

**1** Reference to the **ClusterResourceOverride** admission webhook.

### Additional resources

- [Moving the Cluster Resource Override Operator pods](#)

### 8.5.2.2. Installing the Cluster Resource Override Operator using the CLI

You can use the OpenShift Container Platform CLI to install the Cluster Resource Override Operator to help control overcommit in your cluster.

By default, the installation process creates a Cluster Resource Override Operator pod on a worker node in the **clusterresourceoverride-operator** namespace. You can move this pod to another node, such as an infrastructure node, as needed. Infrastructure nodes are not counted toward the total number of subscriptions that are required to run the environment. For more information, see "Moving the Cluster Resource Override Operator pods".

### Prerequisites

- The Cluster Resource Override Operator has no effect if limits have not been set on containers. You must specify default limits for a project using a **LimitRange** object or configure limits in **Pod** specs for the overrides to apply.

### Procedure

To install the Cluster Resource Override Operator using the CLI:

1. Create a namespace for the Cluster Resource Override Operator:

- a. Create a **Namespace** object YAML file (for example, **cro-namespace.yaml**) for the Cluster Resource Override Operator:

```
apiVersion: v1
kind: Namespace
metadata:
  name: clusterresourceoverride-operator
```

- b. Create the namespace:

```
$ oc create -f <file-name>.yaml
```

For example:

```
$ oc create -f cro-namespace.yaml
```

2. Create an Operator group:

- a. Create an **OperatorGroup** object YAML file (for example, **cro-og.yaml**) for the Cluster Resource Override Operator:

```
apiVersion: operators.coreos.com/v1
kind: OperatorGroup
metadata:
  name: clusterresourceoverride-operator
  namespace: clusterresourceoverride-operator
spec:
  targetNamespaces:
    - clusterresourceoverride-operator
```

- b. Create the Operator Group:

```
$ oc create -f <file-name>.yaml
```

For example:

```
$ oc create -f cro-og.yaml
```

3. Create a subscription:

- a. Create a **Subscription** object YAML file (for example, **cro-sub.yaml**) for the Cluster Resource Override Operator:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: clusterresourceoverride
  namespace: clusterresourceoverride-operator
spec:
  channel: "4.17"
```

```
name: clusterresourceoverride
source: redhat-operators
sourceNamespace: openshift-marketplace
```

- b. Create the subscription:

```
$ oc create -f <file-name>.yaml
```

For example:

```
$ oc create -f cro-sub.yaml
```

4. Create a **ClusterResourceOverride** custom resource (CR) object in the **clusterresourceoverride-operator** namespace:

- a. Change to the **clusterresourceoverride-operator** namespace.

```
$ oc project clusterresourceoverride-operator
```

- b. Create a **ClusterResourceOverride** object YAML file (for example, cro-cr.yaml) for the Cluster Resource Override Operator:

```
apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  name: cluster 1
spec:
  podResourceOverride:
    spec:
      memoryRequestToLimitPercent: 50 2
      cpuRequestToLimitPercent: 25 3
      limitCPUMemoryPercent: 200 4
```

- 1** The name must be **cluster**.
- 2** Optional: Specify the percentage to override the container memory limit, if used, between 1-100. The default is **50**.
- 3** Optional: Specify the percentage to override the container CPU limit, if used, between 1-100. The default is **25**.
- 4** Optional: Specify the percentage to override the container memory limit, if used. Scaling 1 Gi of RAM at 100 percent is equal to 1 CPU core. This is processed before overriding the CPU request, if configured. The default is **200**.

- c. Create the **ClusterResourceOverride** object:

```
$ oc create -f <file-name>.yaml
```

For example:

```
$ oc create -f cro-cr.yaml
```

- Verify the current state of the admission webhook by checking the status of the cluster custom resource.

```
$ oc get clusterresourceoverride cluster -n clusterresourceoverride-operator -o yaml
```

The **mutatingWebhookConfigurationRef** section appears when the webhook is called.

### Example output

```
apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  annotations:
    kubectl.kubernetes.io/last-applied-configuration: |

{"apiVersion":"operator.autoscaling.openshift.io/v1","kind":"ClusterResourceOverride","metad
a":{"annotations":{"name":"cluster"},"spec":{"podResourceOverride":{"spec":
{"cpuRequestToLimitPercent":25,"limitCPUToMemoryPercent":200,"memoryRequestToLimitPe
rcent":50}}}}
creationTimestamp: "2019-12-18T22:35:02Z"
generation: 1
name: cluster
resourceVersion: "127622"
selfLink: /apis/operator.autoscaling.openshift.io/v1/clusterresourceoverrides/cluster
uid: 978fc959-1717-4bd1-97d0-ae00ee111e8d
spec:
  podResourceOverride:
    spec:
      cpuRequestToLimitPercent: 25
      limitCPUToMemoryPercent: 200
      memoryRequestToLimitPercent: 50
status:

# ...

mutatingWebhookConfigurationRef: 1
  apiVersion: admissionregistration.k8s.io/v1
  kind: MutatingWebhookConfiguration
  name: clusterresourceoverrides.admission.autoscaling.openshift.io
  resourceVersion: "127621"
  uid: 98b3b8ae-d5ce-462b-8ab5-a729ea8f38f3

# ...
```

- Reference to the **ClusterResourceOverride** admission webhook.

### Additional resources

- [Moving the Cluster Resource Override Operator pods](#)

#### 8.5.2.3. Configuring cluster-level overcommit

The Cluster Resource Override Operator requires a **ClusterResourceOverride** custom resource (CR) and a label for each project where you want the Operator to control overcommit.



By default, the installation process creates two Cluster Resource Override pods on the control plane nodes in the **clusterresourceoverride-operator** namespace. You can move these pods to other nodes, such as infrastructure nodes, as needed. Infrastructure nodes are not counted toward the total number of subscriptions that are required to run the environment. For more information, see "Moving the Cluster Resource Override Operator pods".

## Prerequisites

- The Cluster Resource Override Operator has no effect if limits have not been set on containers. You must specify default limits for a project using a **LimitRange** object or configure limits in **Pod** specs for the overrides to apply.

## Procedure

To modify cluster-level overcommit:

1. Edit the **ClusterResourceOverride** CR:

```
apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  name: cluster
spec:
  podResourceOverride:
    spec:
      memoryRequestToLimitPercent: 50 1
      cpuRequestToLimitPercent: 25 2
      limitCPUToMemoryPercent: 200 3
# ...
```

- 1** Optional: Specify the percentage to override the container memory limit, if used, between 1-100. The default is **50**.
- 2** Optional: Specify the percentage to override the container CPU limit, if used, between 1-100. The default is **25**.
- 3** Optional: Specify the percentage to override the container memory limit, if used. Scaling 1Gi of RAM at 100 percent is equal to 1 CPU core. This is processed before overriding the CPU request, if configured. The default is **200**.

2. Ensure the following label has been added to the Namespace object for each project where you want the Cluster Resource Override Operator to control overcommit:

```
apiVersion: v1
kind: Namespace
metadata:
# ...

labels:
  clusterresourceoverrides.admission.autoscaling.openshift.io/enabled: "true" 1
# ...
```

- 1 Add this label to each project.

## Additional resources

- [Moving the Cluster Resource Override Operator pods](#)

### 8.5.2.4. Moving the Cluster Resource Override Operator pods

By default, the Cluster Resource Override Operator installation process creates an Operator pod and two Cluster Resource Override pods on nodes in the **clusterresourceoverride-operator** namespace. You can move these pods to other nodes, such as infrastructure nodes, as needed.

You can create and use infrastructure nodes to host only infrastructure components, such as the default router, the integrated container image registry, and the components for cluster metrics and monitoring. These infrastructure nodes are not counted toward the total number of subscriptions that are required to run the environment. For more information about infrastructure nodes, see "Creating infrastructure machine sets".

The following examples shows the Cluster Resource Override pods are deployed to control plane nodes and the Cluster Resource Override Operator pod is deployed to a worker node.

#### Example Cluster Resource Override pods

| NAME                                              | READY  | STATUS | RESTARTS | AGE | IP  | NODE                                                  |
|---------------------------------------------------|--------|--------|----------|-----|-----|-------------------------------------------------------|
| NOMINATED NODE READINESS GATES                    |        |        |          |     |     |                                                       |
| clusterresourceoverride-786b8c898c-9wrdq          |        | 1/1    | Running  | 0   | 23s | 10.128.2.32 ip-10-0-14-183.us-west-2.compute.internal |
|                                                   | <none> | <none> |          |     |     |                                                       |
| clusterresourceoverride-786b8c898c-vn2lf          |        | 1/1    | Running  | 0   | 26s | 10.130.2.10 ip-10-0-20-140.us-west-2.compute.internal |
|                                                   | <none> | <none> |          |     |     |                                                       |
| clusterresourceoverride-operator-6b8b8b656b-lvr62 |        | 1/1    | Running  | 0   | 56m | 10.131.0.33 ip-10-0-2-39.us-west-2.compute.internal   |
|                                                   | <none> | <none> |          |     |     |                                                       |

#### Example node list

| NAME                                      | STATUS | ROLES                | AGE | VERSION |
|-------------------------------------------|--------|----------------------|-----|---------|
| ip-10-0-14-183.us-west-2.compute.internal | Ready  | control-plane,master | 65m | v1.30.4 |
| ip-10-0-2-39.us-west-2.compute.internal   | Ready  | worker               | 58m | v1.30.4 |
| ip-10-0-20-140.us-west-2.compute.internal | Ready  | control-plane,master | 65m | v1.30.4 |
| ip-10-0-23-244.us-west-2.compute.internal | Ready  | infra                | 55m | v1.30.4 |
| ip-10-0-77-153.us-west-2.compute.internal | Ready  | control-plane,master | 65m | v1.30.4 |
| ip-10-0-99-108.us-west-2.compute.internal | Ready  | worker               | 24m | v1.30.4 |
| ip-10-0-24-233.us-west-2.compute.internal | Ready  | infra                | 55m | v1.30.4 |
| ip-10-0-88-109.us-west-2.compute.internal | Ready  | worker               | 24m | v1.30.4 |
| ip-10-0-67-453.us-west-2.compute.internal | Ready  | infra                | 55m | v1.30.4 |

## Procedure

1. Move the Cluster Resource Override Operator pod by adding a node selector to the **Subscription** custom resource (CR) for the Cluster Resource Override Operator.
  - a. Edit the CR:

```
$ oc edit -n clusterresourceoverride-operator subscriptions.operators.coreos.com
clusterresourceoverride
```

- b. Add a node selector to match the node role label on the node where you want to install the Cluster Resource Override Operator pod:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: clusterresourceoverride
  namespace: clusterresourceoverride-operator
# ...
spec:
  config:
    nodeSelector:
      node-role.kubernetes.io/infra: "" ❶
# ...
```

- ❶ Specify the role of the node where you want to deploy the Cluster Resource Override Operator pod.

## NOTE

If the infra node uses taints, you need to add a toleration to the **Subscription** CR.

For example:

```
apiVersion: operators.coreos.com/v1alpha1
kind: Subscription
metadata:
  name: clusterresourceoverride
  namespace: clusterresourceoverride-operator
# ...
spec:
  config:
    nodeSelector:
      node-role.kubernetes.io/infra: ""
    tolerations: ❶
      - key: "node-role.kubernetes.io/infra"
        operator: "Exists"
        effect: "NoSchedule"
```

- ❶ Specifies a toleration for a taint on the infra node.

2. Move the Cluster Resource Override pods by adding a node selector to the **ClusterResourceOverride** custom resource (CR):

- a. Edit the CR:

```
$ oc edit ClusterResourceOverride cluster -n clusterresourceoverride-operator
```

- b. Add a node selector to match the node role label on the infra node:

```

apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  name: cluster
  resourceVersion: "37952"
spec:
  podResourceOverride:
    spec:
      cpuRequestToLimitPercent: 25
      limitCPUToMemoryPercent: 200
      memoryRequestToLimitPercent: 50
  deploymentOverrides:
    replicas: 1 1
    nodeSelector:
      node-role.kubernetes.io/infra: "" 2
# ...

```

- 1** Optional: Specify the number of Cluster Resource Override pods to deploy. The default is **2**. Only one pod is allowed per node.
- 2** Optional: Specify the role of the node where you want to deploy the Cluster Resource Override pods.

## NOTE

If the infra node uses taints, you need to add a toleration to the **ClusterResourceOverride** CR.

For example:

```

apiVersion: operator.autoscaling.openshift.io/v1
kind: ClusterResourceOverride
metadata:
  name: cluster
# ...
spec:
  podResourceOverride:
    spec:
      memoryRequestToLimitPercent: 50
      cpuRequestToLimitPercent: 25
      limitCPUToMemoryPercent: 200
  deploymentOverrides:
    replicas: 3
    nodeSelector:
      node-role.kubernetes.io/worker: ""
    tolerations: 1
      - key: "key"
        operator: "Equal"
        value: "value"
        effect: "NoSchedule"

```

- 1** Specifies a toleration for a taint on the infra node.

## Verification

- You can verify that the pods have moved by using the following command:

```
$ oc get pods -n clusterresourceoverride-operator -o wide
```

The Cluster Resource Override pods are now deployed to the infra nodes.

## Example output

```

NAME                                READY STATUS  RESTARTS  AGE  IP
NODE                                NOMINATED NODE  READINESS GATES
clusterresourceoverride-786b8c898c-9wrdq      1/1   Running  0      23s  10.127.2.25
ip-10-0-23-244.us-west-2.compute.internal <none>      <none>
clusterresourceoverride-786b8c898c-vn2lf      1/1   Running  0      26s  10.128.0.80
ip-10-0-24-233.us-west-2.compute.internal <none>      <none>
clusterresourceoverride-operator-6b8b8b656b-lvr62  1/1   Running  0      56m
10.129.0.71 ip-10-0-67-453.us-west-2.compute.internal <none>      <none>

```

## Additional resources

- [Creating infrastructure machine sets](#)

## 8.5.3. Node-level overcommit

You can use various ways to control overcommit on specific nodes, such as quality of service (QOS) guarantees, CPU limits, or reserve resources. You can also disable overcommit for specific nodes and specific projects.

### 8.5.3.1. Understanding compute resources and containers

The node-enforced behavior for compute resources is specific to the resource type.

#### 8.5.3.1.1. Understanding container CPU requests

A container is guaranteed the amount of CPU it requests and is additionally able to consume excess CPU available on the node, up to any limit specified by the container. If multiple containers are attempting to use excess CPU, CPU time is distributed based on the amount of CPU requested by each container.

For example, if one container requested 500m of CPU time and another container requested 250m of CPU time, then any extra CPU time available on the node is distributed among the containers in a 2:1 ratio. If a container specified a limit, it will be throttled not to use more CPU than the specified limit. CPU requests are enforced using the CFS shares support in the Linux kernel. By default, CPU limits are enforced using the CFS quota support in the Linux kernel over a 100ms measuring interval, though this can be disabled.

#### 8.5.3.1.2. Understanding container memory requests

A container is guaranteed the amount of memory it requests. A container can use more memory than requested, but once it exceeds its requested amount, it could be terminated in a low memory situation on the node. If a container uses less memory than requested, it will not be terminated unless system tasks or daemons need more memory than was accounted for in the node's resource reservation. If a container specifies a limit on memory, it is immediately terminated if it exceeds the limit amount.

### 8.5.3.2. Understanding overcommitment and quality of service classes

A node is *overcommitted* when it has a pod scheduled that makes no request, or when the sum of limits across all pods on that node exceeds available machine capacity.

In an overcommitted environment, it is possible that the pods on the node will attempt to use more compute resource than is available at any given point in time. When this occurs, the node must give priority to one pod over another. The facility used to make this decision is referred to as a Quality of Service (QoS) Class.

A pod is designated as one of three QoS classes with decreasing order of priority:

**Table 8.17. Quality of Service Classes**

| Priority    | Class Name        | Description                                                                                                                                            |
|-------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 (highest) | <b>Guaranteed</b> | If limits and optionally requests are set (not equal to 0) for all resources and they are equal, then the pod is classified as <b>Guaranteed</b> .     |
| 2           | <b>Burstable</b>  | If requests and optionally limits are set (not equal to 0) for all resources, and they are not equal, then the pod is classified as <b>Burstable</b> . |
| 3 (lowest)  | <b>BestEffort</b> | If requests and limits are not set for any of the resources, then the pod is classified as <b>BestEffort</b> .                                         |

Memory is an incompressible resource, so in low memory situations, containers that have the lowest priority are terminated first:

- **Guaranteed** containers are considered top priority, and are guaranteed to only be terminated if they exceed their limits, or if the system is under memory pressure and there are no lower priority containers that can be evicted.
- **Burstable** containers under system memory pressure are more likely to be terminated once they exceed their requests and no other **BestEffort** containers exist.
- **BestEffort** containers are treated with the lowest priority. Processes in these containers are first to be terminated if the system runs out of memory.

#### 8.5.3.2.1. Understanding how to reserve memory across quality of service tiers

You can use the **qos-reserved** parameter to specify a percentage of memory to be reserved by a pod in a particular QoS level. This feature attempts to reserve requested resources to exclude pods from lower QoS classes from using resources requested by pods in higher QoS classes.

OpenShift Container Platform uses the **qos-reserved** parameter as follows:

- A value of **qos-reserved=memory=100%** will prevent the **Burstable** and **BestEffort** QoS classes from consuming memory that was requested by a higher QoS class. This increases the risk of inducing OOM on **BestEffort** and **Burstable** workloads in favor of increasing memory resource guarantees for **Guaranteed** and **Burstable** workloads.
- A value of **qos-reserved=memory=50%** will allow the **Burstable** and **BestEffort** QoS classes to consume half of the memory requested by a higher QoS class.

- A value of **qos-reserved=memory=0%** will allow a **Burstable** and **BestEffort** QoS classes to consume up to the full node allocatable amount if available, but increases the risk that a **Guaranteed** workload will not have access to requested memory. This condition effectively disables this feature.

### 8.5.3.3. Understanding swap memory and QOS

You can disable swap by default on your nodes to preserve quality of service (QOS) guarantees. Otherwise, physical resources on a node can oversubscribe, affecting the resource guarantees the Kubernetes scheduler makes during pod placement.

For example, if two guaranteed pods have reached their memory limit, each container could start using swap memory. Eventually, if there is not enough swap space, processes in the pods can be terminated due to the system being oversubscribed.

Failing to disable swap results in nodes not recognizing that they are experiencing **MemoryPressure**, resulting in pods not receiving the memory they made in their scheduling request. As a result, additional pods are placed on the node to further increase memory pressure, ultimately increasing your risk of experiencing a system out of memory (OOM) event.



#### IMPORTANT

If swap is enabled, any out-of-resource handling eviction thresholds for available memory will not work as expected. Take advantage of out-of-resource handling to allow pods to be evicted from a node when it is under memory pressure, and rescheduled on an alternative node that has no such pressure.

### 8.5.3.4. Understanding nodes overcommitment

In an overcommitted environment, it is important to properly configure your node to provide best system behavior.

When the node starts, it ensures that the kernel tunable flags for memory management are set properly. The kernel should never fail memory allocations unless it runs out of physical memory.

To ensure this behavior, OpenShift Container Platform configures the kernel to always overcommit memory by setting the **vm.overcommit\_memory** parameter to **1**, overriding the default operating system setting.

OpenShift Container Platform also configures the kernel not to panic when it runs out of memory by setting the **vm.panic\_on\_oom** parameter to **0**. A setting of 0 instructs the kernel to call `oom_killer` in an Out of Memory (OOM) condition, which kills processes based on priority.

You can view the current setting by running the following commands on your nodes:

```
$ sysctl -a |grep commit
```

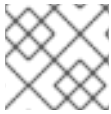
#### Example output

```
#...
vm.overcommit_memory = 0
#...
```

```
$ sysctl -a |grep panic
```

## Example output

```
#...
vm.panic_on_oom = 0
#...
```



### NOTE

The above flags should already be set on nodes, and no further action is required.

You can also perform the following configurations for each node:

- Disable or enforce CPU limits using CPU CFS quotas
- Reserve resources for system processes
- Reserve memory across quality of service tiers

### 8.5.3.5. Disabling or enforcing CPU limits using CPU CFS quotas

Nodes by default enforce specified CPU limits using the Completely Fair Scheduler (CFS) quota support in the Linux kernel.

If you disable CPU limit enforcement, it is important to understand the impact on your node:

- If a container has a CPU request, the request continues to be enforced by CFS shares in the Linux kernel.
- If a container does not have a CPU request, but does have a CPU limit, the CPU request defaults to the specified CPU limit, and is enforced by CFS shares in the Linux kernel.
- If a container has both a CPU request and limit, the CPU request is enforced by CFS shares in the Linux kernel, and the CPU limit has no impact on the node.

### Prerequisites

- Obtain the label associated with the static **MachineConfigPool** CRD for the type of node you want to configure by entering the following command:

```
$ oc edit machineconfigpool <name>
```

For example:

```
$ oc edit machineconfigpool worker
```

### Example output

```
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfigPool
metadata:
  creationTimestamp: "2022-11-16T15:34:25Z"
  generation: 4
```



```
labels:
  pools.operator.machineconfiguration.openshift.io/worker: "" ❶
name: worker
```

- ❶ The label appears under Labels.

### TIP

If the label is not present, add a key/value pair such as:

```
$ oc label machineconfigpool worker custom-kubelet=small-pods
```

### Procedure

1. Create a custom resource (CR) for your configuration change.

#### Sample configuration for a disabling CPU limits

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: disable-cpu-units ❶
spec:
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: "" ❷
  kubeletConfig:
    cpuCfsQuota: false ❸
```

- ❶ Assign a name to CR.
- ❷ Specify the label from the machine config pool.
- ❸ Set the **cpuCfsQuota** parameter to **false**.

2. Run the following command to create the CR:

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

### 8.5.3.6. Reserving resources for system processes

To provide more reliable scheduling and minimize node resource overcommitment, each node can reserve a portion of its resources for use by system daemons that are required to run on your node for your cluster to function. In particular, it is recommended that you reserve resources for incompressible resources such as memory.

### Procedure

To explicitly reserve resources for non-pod processes, allocate node resources by specifying resources available for scheduling. For more details, see [Allocating Resources for Nodes](#).

### 8.5.3.7. Disabling overcommitment for a node

When enabled, overcommitment can be disabled on each node.

#### Procedure

To disable overcommitment in a node run the following command on that node:

```
$ sysctl -w vm.overcommit_memory=0
```

### 8.5.4. Project-level limits

To help control overcommit, you can set per-project resource limit ranges, specifying memory and CPU limits and defaults for a project that overcommit cannot exceed.

For information on project-level resource limits, see [Additional resources](#).

Alternatively, you can disable overcommitment for specific projects.

#### 8.5.4.1. Disabling overcommitment for a project

When enabled, overcommitment can be disabled per-project. For example, you can allow infrastructure components to be configured independently of overcommitment.

#### Procedure

To disable overcommitment in a project:

1. Create or edit the namespace object file.
2. Add the following annotation:

```
apiVersion: v1
kind: Namespace
metadata:
  annotations:
    quota.openshift.io/cluster-resource-override-enabled: "false" 1
# ...
```

**1** Setting this annotation to **false** disables overcommit for this namespace.

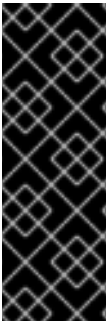
### 8.5.5. Additional resources

- [Setting deployment resources](#).
- [Allocating resources for nodes](#).

## 8.6. CONFIGURING THE LINUX CGROUP VERSION ON YOUR NODES

As of OpenShift Container Platform 4.14, OpenShift Container Platform uses [Linux control group version 2](#) (cgroup v2) in your cluster. If you are using cgroup v1 on OpenShift Container Platform 4.13 or earlier, migrating to OpenShift Container Platform 4.14 or later will not automatically update your cgroup

configuration to version 2. A fresh installation of OpenShift Container Platform 4.14 or later will use cgroup v2 by default. However, you can enable [Linux control group version 1](#) (cgroup v1) upon installation.



### IMPORTANT

cgroup v1 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.

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.

cgroup v2 is the current version of the Linux cgroup API. cgroup v2 offers several improvements over cgroup v1, including a unified hierarchy, safer sub-tree delegation, new features such as [Pressure Stall Information](#), and enhanced resource management and isolation. However, cgroup v2 has different CPU, memory, and I/O management characteristics than cgroup v1. Therefore, some workloads might experience slight differences in memory or CPU usage on clusters that run cgroup v2.

You can change between cgroup v1 and cgroup v2, as needed. Enabling cgroup v1 in OpenShift Container Platform disables all cgroup v2 controllers and hierarchies in your cluster.

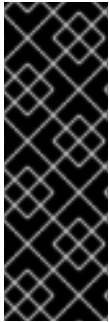


### NOTE

- If you run third-party monitoring and security agents that depend on the cgroup file system, update the agents to a version that supports cgroup v2.
- If you have configured cgroup v2 and run cAdvisor as a stand-alone daemon set for monitoring pods and containers, update cAdvisor to v0.43.0 or later.
- If you deploy Java applications, use versions that fully support cgroup v2, such as the following packages:
  - OpenJDK / HotSpot: jdk8u372, 11.0.16, 15 and later
  - NodeJs 20.3.0 or later
  - IBM Semeru Runtimes: jdk8u345-b01, 11.0.16.0, 17.0.4.0, 18.0.2.0 and later
  - IBM SDK Java Technology Edition Version (IBM Java): 8.0.7.15 and later

## 8.6.1. Configuring Linux cgroup

You can enable [Linux control group version 1](#) (cgroup v1) or [Linux control group version 2](#) (cgroup v2) by editing the `node.config` object. The default is cgroup v2.



## IMPORTANT

cgroup v1 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.

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.

### Prerequisites

- You have a running OpenShift Container Platform cluster that uses version 4.12 or later.
- You are logged in to the cluster as a user with administrative privileges.

### Procedure

1. Enable cgroup v1 on nodes:
  - a. Edit the **node.config** object:
 

```
$ oc edit nodes.config/cluster
```
  - b. Edit the **spec.cgroupMode** parameter:

#### Example node.config object

```
apiVersion: config.openshift.io/v2
kind: Node
metadata:
  annotations:
    include.release.openshift.io/ibm-cloud-managed: "true"
    include.release.openshift.io/self-managed-high-availability: "true"
    include.release.openshift.io/single-node-developer: "true"
    release.openshift.io/create-only: "true"
  creationTimestamp: "2022-07-08T16:02:51Z"
  generation: 1
  name: cluster
  ownerReferences:
  - apiVersion: config.openshift.io/v2
    kind: ClusterVersion
    name: version
    uid: 36282574-bf9f-409e-a6cd-3032939293eb
  resourceVersion: "1865"
  uid: 0c0f7a4c-4307-4187-b591-6155695ac85b
spec:
  cgroupMode: "v1" 1
  ...
```

- 1** Specify **v1** to enable cgroup v1 or **v2** for cgroup v2.

### Verification

1. Check the machine configs to see that the new machine configs were added:

```
$ oc get mc
```

### Example output

```

NAME                                     GENERATEDBYCONTROLLER
IGNITIONVERSION AGE
00-master                                     52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0
33m
00-worker                                     52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0
33m
01-master-container-runtime                 52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
01-master-kubelet                           52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
01-worker-container-runtime                 52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
01-worker-kubelet                           52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
97-master-generated-kubelet                 52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
99-worker-generated-kubelet                 52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
99-master-generated-registries              52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
99-master-ssh                               3.2.0 40m
99-worker-generated-registries              52dd3ba6a9a527fc3ab42afac8d12b693534c8c9
3.2.0 33m
99-worker-ssh                               3.2.0 40m
rendered-master-23d4317815a5f854bd3553d689cfe2e9
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0 10s ❶
rendered-master-23e785de7587df95a4b517e0647e5ab7
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0 33m
rendered-worker-5d596d9293ca3ea80c896a1191735bb1
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0 33m
rendered-worker-dcc7f1b92892d34db74d6832bcc9ccd4
52dd3ba6a9a527fc3ab42afac8d12b693534c8c9 3.2.0 10s

```

- ❶ New machine configs are created, as expected.

2. Check that the new **kernelArguments** were added to the new machine configs:

```
$ oc describe mc <name>
```

### Example output for cgroup v2

```

apiVersion: machineconfiguration.openshift.io/v2
kind: MachineConfig
metadata:
  labels:
    machineconfiguration.openshift.io/role: worker
  name: 05-worker-kernelarg-selinuxpermissive

```

```
spec:
  kernelArguments:
    systemd_unified_cgroup_hierarchy=1 ❶
    cgroup_no_v1="all" ❷
    psi=1 ❸
```

- ❶ Enables cgroup v2 in systemd.
- ❷ Disables cgroup v1.
- ❸ Enables the Linux Pressure Stall Information (PSI) feature.

### Example output for cgroup v1

```
apiVersion: machineconfiguration.openshift.io/v2
kind: MachineConfig
metadata:
  labels:
    machineconfiguration.openshift.io/role: worker
  name: 05-worker-kernelarg-selinuxpermissive
spec:
  kernelArguments:
    systemd.unified_cgroup_hierarchy=0 ❶
    systemd.legacy_systemd_cgroup_controller=1 ❷
```

- ❶ Disables cgroup v2.
- ❷ Enables cgroup v1 in systemd.

3. Check the nodes to see that scheduling on the nodes is disabled. This indicates that the change is being applied:

```
$ oc get nodes
```

### Example output

| NAME                                    | STATUS                   | ROLES  | AGE | VERSION |
|-----------------------------------------|--------------------------|--------|-----|---------|
| ci-ln-fm1qnt-72292-99kt6-master-0       | Ready,SchedulingDisabled | master | 58m | v1.30.3 |
| ci-ln-fm1qnt-72292-99kt6-master-1       | Ready                    | master | 58m | v1.30.3 |
| ci-ln-fm1qnt-72292-99kt6-master-2       | Ready                    | master | 58m | v1.30.3 |
| ci-ln-fm1qnt-72292-99kt6-worker-a-h5gt4 | Ready,SchedulingDisabled | worker | 48m | v1.30.3 |
| ci-ln-fm1qnt-72292-99kt6-worker-b-7vtmd | Ready                    | worker | 48m | v1.30.3 |
| ci-ln-fm1qnt-72292-99kt6-worker-c-rhzkv | Ready                    | worker | 48m | v1.30.3 |

4. After a node returns to the **Ready** state, start a debug session for that node:

```
$ oc debug node/<node_name>
```

5. Set **/host** as the root directory within the debug shell:

■

```
sh-4.4# chroot /host
```

- Check that the **sys/fs/cgroup/cgroup2fs** or **sys/fs/cgroup/tmpfs** file is present on your nodes:

```
$ stat -c %T -f /sys/fs/cgroup
```

#### Example output for cgroup v2

```
cgroup2fs
```

#### Example output for cgroup v1

```
tmpfs
```

#### Additional resources

- [OpenShift Container Platform installation overview](#)

## 8.7. ENABLING FEATURES USING FEATURE GATES

As an administrator, you can use feature gates to enable features that are not part of the default set of features.

### 8.7.1. Understanding feature gates

You can use the **FeatureGate** custom resource (CR) to enable specific feature sets in your cluster. A feature set is a collection of OpenShift Container Platform features that are not enabled by default.

You can activate the following feature set by using the **FeatureGate** CR:

- TechPreviewNoUpgrade.** This feature set is a subset of the current Technology Preview features. This feature set allows you to enable these Technology Preview features on test clusters, where you can fully test them, while leaving the features disabled on production clusters.



#### WARNING

Enabling the **TechPreviewNoUpgrade** feature set on your cluster cannot be undone and prevents minor version updates. You should not enable this feature set on production clusters.

The following Technology Preview features are enabled by this feature set:

- External cloud providers. Enables support for external cloud providers for clusters on vSphere, AWS, Azure, and GCP. Support for OpenStack is GA. This is an internal feature that most users do not need to interact with. (**ExternalCloudProvider**)

- Shared Resources CSI Driver in OpenShift Builds. Enables the Container Storage Interface (CSI). (**CSIDriverSharedResource**)
- Swap memory on nodes. Enables swap memory use for OpenShift Container Platform workloads on a per-node basis. (**NodeSwap**)
- OpenStack Machine API Provider. This gate has no effect and is planned to be removed from this feature set in a future release. (**MachineAPIProviderOpenStack**)
- Insights Operator. Enables the **InsightsDataGather** CRD, which allows users to configure some Insights data gathering options. The feature set also enables the **DataGather** CRD, which allows users to run Insights data gathering on-demand. (**InsightsConfigAPI**)
- Dynamic Resource Allocation API. Enables a new API for requesting and sharing resources between pods and containers. This is an internal feature that most users do not need to interact with. (**DynamicResourceAllocation**)
- Pod security admission enforcement. Enables the restricted enforcement mode for pod security admission. Instead of only logging a warning, pods are rejected if they violate pod security standards. (**OpenShiftPodSecurityAdmission**)
- StatefulSet pod availability upgrading limits. Enables users to define the maximum number of statefulset pods unavailable during updates which reduces application downtime. (**MaxUnavailableStatefulSet**)
- Admin Network Policy and Baseline Admin Network Policy. Enables **AdminNetworkPolicy** and **BaselineAdminNetworkPolicy** resources, which are part of the Network Policy V2 API, in clusters running the OVN-Kubernetes CNI plugin. Cluster administrators can apply cluster-scoped policies and safeguards for an entire cluster before namespaces are created. Network administrators can secure clusters by enforcing network traffic controls that cannot be overridden by users. Network administrators can enforce optional baseline network traffic controls that can be overridden by users in the cluster, if necessary. Currently, these APIs support only expressing policies for intra-cluster traffic. (**AdminNetworkPolicy**)
- **gcpLabelsTags**
- **vSphereStaticIPs**
- **routeExternalCertificate**
- **automatedEtcdBackup**
- **gcpClusterHostedDNS**
- **vSphereControlPlaneMachineset**
- **dnsNameResolver**
- **machineConfigNodes**
- **metricsServer**
- **installAlternateInfrastructureAWS**
- **mixedCPUsAllocation**
- **managedBootImages**



- **onClusterBuild**
- **signatureStores**
- **SigstoreImageVerification**
- **DisableKubeletCloudCredentialProviders**
- **BareMetalLoadBalancer**
- **ClusterAPIInstallAWS**
- **ClusterAPIInstallAzure**
- **ClusterAPIInstallNutanix**
- **ClusterAPIInstallOpenStack**
- **ClusterAPIInstallVSphere**
- **HardwareSpeed**
- **KMSv1**
- **NetworkDiagnosticsConfig**
- **VSphereDriverConfiguration**
- **ExternalOIDC**
- **ChunkSizeMiB**
- **ClusterAPIInstallGCP**
- **ClusterAPIInstallPowerVS**
- **EtcBackendQuota**
- **InsightsConfig**
- **InsightsOnDemandDataGather**
- **MetricsCollectionProfiles**
- **NewOLM**
- **NodeDisruptionPolicy**
- **PinnedImages**
- **PlatformOperators**
- **ServiceAccountTokenNodeBinding**
- **TranslateStreamCloseWebsocketRequests**
- **UpgradeStatus**

- **VSphereMultiVCenters**
- **VolumeGroupSnapshot**
- **AdditionalRoutingCapabilities**
- **BootcNodeManagement**
- **ClusterMonitoringConfig**
- **DNSNameResolver**
- **ManagedBootImagesAWS**
- **NetworkSegmentation**
- **OVNObservability**
- **PersistentIPsForVirtualization**
- **ProcMountType**
- **RouteAdvertisements**
- **UserNamespacesSupport**
- **AWSEFSDriverVolumeMetrics**
- **AlibabaPlatform**
- **AzureWorkloadIdentity**
- **BuildCSIVolumes**
- **CloudDualStackNodeIPs**
- **ExternalCloudProviderAzure**
- **ExternalCloudProviderExternal**
- **ExternalCloudProviderGCP**
- **IngressControllerLBSubnetsAWS**
- **MultiArchInstallAWS**
- **MultiArchInstallGCP**
- **NetworkLiveMigration**
- **PrivateHostedZoneAWS**
- **SetEIPForNLBIngressController**
- **ValidatingAdmissionPolicy**

For more information about the features activated by the **TechPreviewNoUpgrade** feature gate, see the following topics:

- [Shared Resources CSI Driver and Build CSI Volumes in OpenShift Builds](#)
- [CSI inline ephemeral volumes](#)
- [Swap memory on nodes](#)
- [Managing machines with the Cluster API](#)
- [Disabling the Insights Operator gather operations](#)
- [Enabling the Insights Operator gather operations](#)
- [Running an Insights Operator gather operation](#)
- [Managing the default storage class](#)
- [Pod security admission enforcement](#)

## 8.7.2. Enabling feature sets at installation

You can enable feature sets for all nodes in the cluster by editing the **install-config.yaml** file before you deploy the cluster.

### Prerequisites

- You have an **install-config.yaml** file.

### Procedure

1. Use the **featureSet** parameter to specify the name of the feature set you want to enable, such as **TechPreviewNoUpgrade**:



#### WARNING

Enabling the **TechPreviewNoUpgrade** feature set on your cluster cannot be undone and prevents minor version updates. You should not enable this feature set on production clusters.

### Sample **install-config.yaml** file with an enabled feature set

```
compute:
- hyperthreading: Enabled
  name: worker
  platform:
    aws:
      rootVolume:
        iops: 2000
        size: 500
        type: io1
      metadataService:
```

```

authentication: Optional
type: c5.4xlarge
zones:
- us-west-2c
replicas: 3
featureSet: TechPreviewNoUpgrade

```

2. Save the file and reference it when using the installation program to deploy the cluster.

## Verification

You can verify that the feature gates are enabled by looking at the **kubelet.conf** file on a node after the nodes return to the ready state.

1. From the **Administrator** perspective in the web console, navigate to **Compute → Nodes**.
2. Select a node.
3. In the **Node details** page, click **Terminal**.
4. In the terminal window, change your root directory to **/host**:

```
sh-4.2# chroot /host
```

5. View the **kubelet.conf** file:

```
sh-4.2# cat /etc/kubernetes/kubelet.conf
```

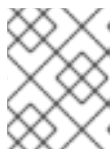
### Sample output

```

# ...
featureGates:
  InsightsOperatorPullingSCA: true,
  LegacyNodeRoleBehavior: false
# ...

```

The features that are listed as **true** are enabled on your cluster.



### NOTE

The features listed vary depending upon the OpenShift Container Platform version.

## 8.7.3. Enabling feature sets using the web console

You can use the OpenShift Container Platform web console to enable feature sets for all of the nodes in a cluster by editing the **FeatureGate** custom resource (CR).

### Procedure

To enable feature sets:

1. In the OpenShift Container Platform web console, switch to the **Administration → Custom Resource Definitions** page.

2. On the **Custom Resource Definitions** page, click **FeatureGate**.
3. On the **Custom Resource Definition Details** page, click the **Instances** tab.
4. Click the **cluster** feature gate, then click the **YAML** tab.
5. Edit the **cluster** instance to add specific feature sets:



### WARNING

Enabling the **TechPreviewNoUpgrade** feature set on your cluster cannot be undone and prevents minor version updates. You should not enable this feature set on production clusters.

### Sample Feature Gate custom resource

```
apiVersion: config.openshift.io/v1
kind: FeatureGate
metadata:
  name: cluster 1
# ...
spec:
  featureSet: TechPreviewNoUpgrade 2
```

**1** The name of the **FeatureGate** CR must be **cluster**.

**2** Add the feature set that you want to enable:

- **TechPreviewNoUpgrade** enables specific Technology Preview features.

After you save the changes, new machine configs are created, the machine config pools are updated, and scheduling on each node is disabled while the change is being applied.

### Verification

You can verify that the feature gates are enabled by looking at the **kubelet.conf** file on a node after the nodes return to the ready state.

1. From the **Administrator** perspective in the web console, navigate to **Compute → Nodes**.
2. Select a node.
3. In the **Node details** page, click **Terminal**.
4. In the terminal window, change your root directory to **/host**:

```
sh-4.2# chroot /host
```

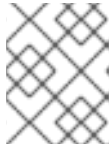
5. View the **kubelet.conf** file:

```
sh-4.2# cat /etc/kubernetes/kubelet.conf
```

### Sample output

```
# ...
featureGates:
  InsightsOperatorPullingSCA: true,
  LegacyNodeRoleBehavior: false
# ...
```

The features that are listed as **true** are enabled on your cluster.



#### NOTE

The features listed vary depending upon the OpenShift Container Platform version.

### 8.7.4. Enabling feature sets using the CLI

You can use the OpenShift CLI (**oc**) to enable feature sets for all of the nodes in a cluster by editing the **FeatureGate** custom resource (CR).

#### Prerequisites

- You have installed the OpenShift CLI (**oc**).

#### Procedure

To enable feature sets:

- Edit the **FeatureGate** CR named **cluster**:

```
$ oc edit featuregate cluster
```



#### WARNING

Enabling the **TechPreviewNoUpgrade** feature set on your cluster cannot be undone and prevents minor version updates. You should not enable this feature set on production clusters.

### Sample FeatureGate custom resource

```
apiVersion: config.openshift.io/v1
kind: FeatureGate
metadata:
  name: cluster 1
```

```
# ...
spec:
  featureSet: TechPreviewNoUpgrade 2
```

- 1 The name of the **FeatureGate** CR must be **cluster**.
- 2 Add the feature set that you want to enable:
  - **TechPreviewNoUpgrade** enables specific Technology Preview features.

After you save the changes, new machine configs are created, the machine config pools are updated, and scheduling on each node is disabled while the change is being applied.

## Verification

You can verify that the feature gates are enabled by looking at the **kubelet.conf** file on a node after the nodes return to the ready state.

1. From the **Administrator** perspective in the web console, navigate to **Compute → Nodes**.
2. Select a node.
3. In the **Node details** page, click **Terminal**.
4. In the terminal window, change your root directory to **/host**:

```
sh-4.2# chroot /host
```

5. View the **kubelet.conf** file:

```
sh-4.2# cat /etc/kubernetes/kubelet.conf
```

## Sample output

```
# ...
featureGates:
  InsightsOperatorPullingSCA: true,
  LegacyNodeRoleBehavior: false
# ...
```

The features that are listed as **true** are enabled on your cluster.



### NOTE

The features listed vary depending upon the OpenShift Container Platform version.

## 8.8. IMPROVING CLUSTER STABILITY IN HIGH LATENCY ENVIRONMENTS USING WORKER LATENCY PROFILES

If the cluster administrator has performed latency tests for platform verification, they can discover the need to adjust the operation of the cluster to ensure stability in cases of high latency. The cluster administrator need change only one parameter, recorded in a file, which controls four parameters

affecting how supervisory processes read status and interpret the health of the cluster. Changing only the one parameter provides cluster tuning in an easy, supportable manner.

The **Kubelet** process provides the starting point for monitoring cluster health. The **Kubelet** sets status values for all nodes in the OpenShift Container Platform cluster. The Kubernetes Controller Manager (**kube controller**) reads the status values every 10 seconds, by default. If the **kube controller** cannot read a node status value, it loses contact with that node after a configured period. The default behavior is:

1. The node controller on the control plane updates the node health to **Unhealthy** and marks the node **Ready** condition `Unknown`.
2. In response, the scheduler stops scheduling pods to that node.
3. The Node Lifecycle Controller adds a **node.kubernetes.io/unreachable** taint with a **NoExecute** effect to the node and schedules any pods on the node for eviction after five minutes, by default.

This behavior can cause problems if your network is prone to latency issues, especially if you have nodes at the network edge. In some cases, the Kubernetes Controller Manager might not receive an update from a healthy node due to network latency. The **Kubelet** evicts pods from the node even though the node is healthy.

To avoid this problem, you can use *worker latency profiles* to adjust the frequency that the **Kubelet** and the Kubernetes Controller Manager wait for status updates before taking action. These adjustments help to ensure that your cluster runs properly if network latency between the control plane and the worker nodes is not optimal.

These worker latency profiles contain three sets of parameters that are pre-defined with carefully tuned values to control the reaction of the cluster to increased latency. No need to experimentally find the best values manually.

You can configure worker latency profiles when installing a cluster or at any time you notice increased latency in your cluster network.

### 8.8.1. Understanding worker latency profiles

Worker latency profiles are four different categories of carefully-tuned parameters. The four parameters which implement these values are **node-status-update-frequency**, **node-monitor-grace-period**, **default-not-ready-toleration-seconds** and **default-unreachable-toleration-seconds**. These parameters can use values which allow you control the reaction of the cluster to latency issues without needing to determine the best values using manual methods.



#### IMPORTANT

Setting these parameters manually is not supported. Incorrect parameter settings adversely affect cluster stability.

All worker latency profiles configure the following parameters:

#### **node-status-update-frequency**

Specifies how often the kubelet posts node status to the API server.

#### **node-monitor-grace-period**



Specifies the amount of time in seconds that the Kubernetes Controller Manager waits for an update from a kubelet before marking the node unhealthy and adding the **node.kubernetes.io/not-ready** or **node.kubernetes.io/unreachable** taint to the node.

#### default-not-ready-toleration-seconds

Specifies the amount of time in seconds after marking a node unhealthy that the Kube API Server Operator waits before evicting pods from that node.

#### default-unreachable-toleration-seconds

Specifies the amount of time in seconds after marking a node unreachable that the Kube API Server Operator waits before evicting pods from that node.

The following Operators monitor the changes to the worker latency profiles and respond accordingly:

- The Machine Config Operator (MCO) updates the **node-status-update-frequency** parameter on the worker nodes.
- The Kubernetes Controller Manager updates the **node-monitor-grace-period** parameter on the control plane nodes.
- The Kubernetes API Server Operator updates the **default-not-ready-toleration-seconds** and **default-unreachable-toleration-seconds** parameters on the control plane nodes.

Although the default configuration works in most cases, OpenShift Container Platform offers two other worker latency profiles for situations where the network is experiencing higher latency than usual. The three worker latency profiles are described in the following sections:

#### Default worker latency profile

With the **Default** profile, each **Kubelet** updates its status every 10 seconds ( **node-status-update-frequency**). The **Kube Controller Manager** checks the statuses of **Kubelet** every 5 seconds ( **node-monitor-grace-period**).

The Kubernetes Controller Manager waits 40 seconds for a status update from **Kubelet** before considering the **Kubelet** unhealthy. If no status is made available to the Kubernetes Controller Manager, it then marks the node with the **node.kubernetes.io/not-ready** or **node.kubernetes.io/unreachable** taint and evicts the pods on that node.

If a pod on that node has the **NoExecute** taint, the pod is run according to **tolerationSeconds**. If the pod has no taint, it will be evicted in 300 seconds (**default-not-ready-toleration-seconds** and **default-unreachable-toleration-seconds** settings of the **Kube API Server**).

| Profile | Component                      | Parameter                                   | Value |
|---------|--------------------------------|---------------------------------------------|-------|
| Default | kubelet                        | <b>node-status-update-frequency</b>         | 10s   |
|         | Kubelet Controller Manager     | <b>node-monitor-grace-period</b>            | 40s   |
|         | Kubernetes API Server Operator | <b>default-not-ready-toleration-seconds</b> | 300s  |

| Profile | Component                            | Parameter                                     | Value |
|---------|--------------------------------------|-----------------------------------------------|-------|
|         | Kubernetes<br>API Server<br>Operator | <b>default-unreachable-toleration-seconds</b> | 300s  |

### Medium worker latency profile

Use the **MediumUpdateAverageReaction** profile if the network latency is slightly higher than usual. The **MediumUpdateAverageReaction** profile reduces the frequency of kubelet updates to 20 seconds and changes the period that the Kubernetes Controller Manager waits for those updates to 2 minutes. The pod eviction period for a pod on that node is reduced to 60 seconds. If the pod has the **tolerationSeconds** parameter, the eviction waits for the period specified by that parameter.

The Kubernetes Controller Manager waits for 2 minutes to consider a node unhealthy. In another minute, the eviction process starts.

| Profile                     | Component                            | Parameter                                     | Value |
|-----------------------------|--------------------------------------|-----------------------------------------------|-------|
| MediumUpdateAverageReaction | kubelet                              | <b>node-status-update-frequency</b>           | 20s   |
|                             | Kubelet<br>Controller<br>Manager     | <b>node-monitor-grace-period</b>              | 2m    |
|                             | Kubernetes<br>API Server<br>Operator | <b>default-not-ready-toleration-seconds</b>   | 60s   |
|                             | Kubernetes<br>API Server<br>Operator | <b>default-unreachable-toleration-seconds</b> | 60s   |

### Low worker latency profile

Use the **LowUpdateSlowReaction** profile if the network latency is extremely high.

The **LowUpdateSlowReaction** profile reduces the frequency of kubelet updates to 1 minute and changes the period that the Kubernetes Controller Manager waits for those updates to 5 minutes. The pod eviction period for a pod on that node is reduced to 60 seconds. If the pod has the **tolerationSeconds** parameter, the eviction waits for the period specified by that parameter.

The Kubernetes Controller Manager waits for 5 minutes to consider a node unhealthy. In another minute, the eviction process starts.

| Profile | Component | Parameter | Value |
|---------|-----------|-----------|-------|
|---------|-----------|-----------|-------|

| Profile               | Component                            | Parameter                                     | Value |
|-----------------------|--------------------------------------|-----------------------------------------------|-------|
| LowUpdateSlowReaction | kubelet                              | <b>node-status-update-frequency</b>           | 1m    |
|                       | Kubelet<br>Controller<br>Manager     | <b>node-monitor-grace-period</b>              | 5m    |
|                       | Kubernetes<br>API Server<br>Operator | <b>default-not-ready-toleration-seconds</b>   | 60s   |
|                       | Kubernetes<br>API Server<br>Operator | <b>default-unreachable-toleration-seconds</b> | 60s   |

## 8.8.2. Using and changing worker latency profiles

To change a worker latency profile to deal with network latency, edit the **node.config** object to add the name of the profile. You can change the profile at any time as latency increases or decreases.

You must move one worker latency profile at a time. For example, you cannot move directly from the **Default** profile to the **LowUpdateSlowReaction** worker latency profile. You must move from the **Default** worker latency profile to the **MediumUpdateAverageReaction** profile first, then to **LowUpdateSlowReaction**. Similarly, when returning to the **Default** profile, you must move from the low profile to the medium profile first, then to **Default**.



### NOTE

You can also configure worker latency profiles upon installing an OpenShift Container Platform cluster.

### Procedure

To move from the default worker latency profile:

1. Move to the medium worker latency profile:
  - a. Edit the **node.config** object:
 

```
$ oc edit nodes.config/cluster
```
  - b. Add **spec.workerLatencyProfile: MediumUpdateAverageReaction:**

#### Example node.config object

```
apiVersion: config.openshift.io/v1
kind: Node
```

```

metadata:
  annotations:
    include.release.openshift.io/ibm-cloud-managed: "true"
    include.release.openshift.io/self-managed-high-availability: "true"
    include.release.openshift.io/single-node-developer: "true"
    release.openshift.io/create-only: "true"
  creationTimestamp: "2022-07-08T16:02:51Z"
  generation: 1
  name: cluster
  ownerReferences:
  - apiVersion: config.openshift.io/v1
    kind: ClusterVersion
    name: version
    uid: 36282574-bf9f-409e-a6cd-3032939293eb
  resourceVersion: "1865"
  uid: 0c0f7a4c-4307-4187-b591-6155695ac85b
spec:
  workerLatencyProfile: MediumUpdateAverageReaction 1

# ...

```

- 1** Specifies the medium worker latency policy.

Scheduling on each worker node is disabled as the change is being applied.

2. Optional: Move to the low worker latency profile:

- a. Edit the **node.config** object:

```
$ oc edit nodes.config/cluster
```

- b. Change the **spec.workerLatencyProfile** value to **LowUpdateSlowReaction**:

### Example node.config object

```

apiVersion: config.openshift.io/v1
kind: Node
metadata:
  annotations:
    include.release.openshift.io/ibm-cloud-managed: "true"
    include.release.openshift.io/self-managed-high-availability: "true"
    include.release.openshift.io/single-node-developer: "true"
    release.openshift.io/create-only: "true"
  creationTimestamp: "2022-07-08T16:02:51Z"
  generation: 1
  name: cluster
  ownerReferences:
  - apiVersion: config.openshift.io/v1
    kind: ClusterVersion
    name: version
    uid: 36282574-bf9f-409e-a6cd-3032939293eb
  resourceVersion: "1865"
  uid: 0c0f7a4c-4307-4187-b591-6155695ac85b
spec:

```

```
workerLatencyProfile: LowUpdateSlowReaction 1
```

```
# ...
```

- 1** Specifies use of the low worker latency policy.

Scheduling on each worker node is disabled as the change is being applied.

## Verification

- When all nodes return to the **Ready** condition, you can use the following command to look in the Kubernetes Controller Manager to ensure it was applied:

```
$ oc get KubeControllerManager -o yaml | grep -i workerlatency -A 5 -B 5
```

## Example output

```
# ...
- lastTransitionTime: "2022-07-11T19:47:10Z"
  reason: ProfileUpdated
  status: "False"
  type: WorkerLatencyProfileProgressing
- lastTransitionTime: "2022-07-11T19:47:10Z" 1
  message: all static pod revision(s) have updated latency profile
  reason: ProfileUpdated
  status: "True"
  type: WorkerLatencyProfileComplete
- lastTransitionTime: "2022-07-11T19:20:11Z"
  reason: AsExpected
  status: "False"
  type: WorkerLatencyProfileDegraded
- lastTransitionTime: "2022-07-11T19:20:36Z"
  status: "False"
# ...
```

- 1** Specifies that the profile is applied and active.

To change the medium profile to default or change the default to medium, edit the **node.config** object and set the **spec.workerLatencyProfile** parameter to the appropriate value.

## CHAPTER 9. REMOTE WORKER NODES ON THE NETWORK EDGE

### 9.1. USING REMOTE WORKER NODES AT THE NETWORK EDGE

You can configure OpenShift Container Platform clusters with nodes located at your network edge. In this topic, they are called *remote worker nodes*. A typical cluster with remote worker nodes combines on-premise master and worker nodes with worker nodes in other locations that connect to the cluster. This topic is intended to provide guidance on best practices for using remote worker nodes and does not contain specific configuration details.

There are multiple use cases across different industries, such as telecommunications, retail, manufacturing, and government, for using a deployment pattern with remote worker nodes. For example, you can separate and isolate your projects and workloads by combining the remote worker nodes into [Kubernetes zones](#).

However, having remote worker nodes can introduce higher latency, intermittent loss of network connectivity, and other issues. Among the challenges in a cluster with remote worker node are:

- **Network separation:** The OpenShift Container Platform control plane and the remote worker nodes must be able to communicate with each other. Because of the distance between the control plane and the remote worker nodes, network issues could prevent this communication. See [Network separation with remote worker nodes](#) for information on how OpenShift Container Platform responds to network separation and for methods to diminish the impact to your cluster.
- **Power outage:** Because the control plane and remote worker nodes are in separate locations, a power outage at the remote location or at any point between the two can negatively impact your cluster. See [Power loss on remote worker nodes](#) for information on how OpenShift Container Platform responds to a node losing power and for methods to diminish the impact to your cluster.
- **Latency spikes or temporary reduction in throughput** As with any network, any changes in network conditions between your cluster and the remote worker nodes can negatively impact your cluster. OpenShift Container Platform offers multiple *worker latency profiles* that let you control the reaction of the cluster to latency issues.

Note the following limitations when planning a cluster with remote worker nodes:

- OpenShift Container Platform does not support remote worker nodes that use a different cloud provider than the on-premise cluster uses.
- Moving workloads from one Kubernetes zone to a different Kubernetes zone can be problematic due to system and environment issues, such as a specific type of memory not being available in a different zone.
- Proxies and firewalls can present additional limitations that are beyond the scope of this document. See the relevant OpenShift Container Platform documentation for how to address such limitations, such as [Configuring your firewall](#).
- You are responsible for configuring and maintaining L2/L3-level network connectivity between the control plane and the network-edge nodes.

#### 9.1.1. Adding remote worker nodes

Adding remote worker nodes to a cluster involves some additional considerations.

- You must ensure that a route or a default gateway is in place to route traffic between the control plane and every remote worker node.
- You must place the Ingress VIP on the control plane.
- Adding remote worker nodes with user-provisioned infrastructure is identical to adding other worker nodes.
- To add remote worker nodes to an installer-provisioned cluster at install time, specify the subnet for each worker node in the **install-config.yaml** file before installation. There are no additional settings required for the DHCP server. You must use virtual media, because the remote worker nodes will not have access to the local provisioning network.
- To add remote worker nodes to an installer-provisioned cluster deployed with a provisioning network, ensure that **virtualMediaViaExternalNetwork** flag is set to **true** in the **install-config.yaml** file so that it will add the nodes using virtual media. Remote worker nodes will not have access to the local provisioning network. They must be deployed with virtual media rather than PXE. Additionally, specify each subnet for each group of remote worker nodes and the control plane nodes in the DHCP server.

#### Additional resources

- [Establishing communications between subnets](#)
- [Configuring host network interfaces for subnets](#)
- [Configuring network components to run on the control plane](#)

### 9.1.2. Network separation with remote worker nodes

All nodes send heartbeats to the Kubernetes Controller Manager Operator (kube controller) in the OpenShift Container Platform cluster every 10 seconds. If the cluster does not receive heartbeats from a node, OpenShift Container Platform responds using several default mechanisms.

OpenShift Container Platform is designed to be resilient to network partitions and other disruptions. You can mitigate some of the more common disruptions, such as interruptions from software upgrades, network splits, and routing issues. Mitigation strategies include ensuring that pods on remote worker nodes request the correct amount of CPU and memory resources, configuring an appropriate replication policy, using redundancy across zones, and using Pod Disruption Budgets on workloads.

If the kube controller loses contact with a node after a configured period, the node controller on the control plane updates the node health to **Unhealthy** and marks the node **Ready** condition as **Unknown**. In response, the scheduler stops scheduling pods to that node. The on-premise node controller adds a **node.kubernetes.io/unreachable** taint with a **NoExecute** effect to the node and schedules pods on the node for eviction after five minutes, by default.

If a workload controller, such as a **Deployment** object or **StatefulSet** object, is directing traffic to pods on the unhealthy node and other nodes can reach the cluster, OpenShift Container Platform routes the traffic away from the pods on the node. Nodes that cannot reach the cluster do not get updated with the new traffic routing. As a result, the workloads on those nodes might continue to attempt to reach the unhealthy node.

You can mitigate the effects of connection loss by:

- using daemon sets to create pods that tolerate the taints
- using static pods that automatically restart if a node goes down
- using Kubernetes zones to control pod eviction
- configuring pod tolerations to delay or avoid pod eviction
- configuring the kubelet to control the timing of when it marks nodes as unhealthy.

For more information on using these objects in a cluster with remote worker nodes, see [About remote worker node strategies](#).

### 9.1.3. Power loss on remote worker nodes

If a remote worker node loses power or restarts ungracefully, OpenShift Container Platform responds using several default mechanisms.

If the Kubernetes Controller Manager Operator (kube controller) loses contact with a node after a configured period, the control plane updates the node health to **Unhealthy** and marks the node **Ready** condition as **Unknown**. In response, the scheduler stops scheduling pods to that node. The on-premise node controller adds a **node.kubernetes.io/unreachable** taint with a **NoExecute** effect to the node and schedules pods on the node for eviction after five minutes, by default.

On the node, the pods must be restarted when the node recovers power and reconnects with the control plane.



#### NOTE

If you want the pods to restart immediately upon restart, use static pods.

After the node restarts, the kubelet also restarts and attempts to restart the pods that were scheduled on the node. If the connection to the control plane takes longer than the default five minutes, the control plane cannot update the node health and remove the **node.kubernetes.io/unreachable** taint. On the node, the kubelet terminates any running pods. When these conditions are cleared, the scheduler can start scheduling pods to that node.

You can mitigate the effects of power loss by:

- using daemon sets to create pods that tolerate the taints
- using static pods that automatically restart with a node
- configuring pods tolerations to delay or avoid pod eviction
- configuring the kubelet to control the timing of when the node controller marks nodes as unhealthy.

For more information on using these objects in a cluster with remote worker nodes, see [About remote worker node strategies](#).

### 9.1.4. Latency spikes or temporary reduction in throughput to remote workers

If the cluster administrator has performed latency tests for platform verification, they can discover the need to adjust the operation of the cluster to ensure stability in cases of high latency. The cluster administrator need change only one parameter, recorded in a file, which controls four parameters



affecting how supervisory processes read status and interpret the health of the cluster. Changing only the one parameter provides cluster tuning in an easy, supportable manner.

The **Kubelet** process provides the starting point for monitoring cluster health. The **Kubelet** sets status values for all nodes in the OpenShift Container Platform cluster. The Kubernetes Controller Manager (**kube controller**) reads the status values every 10 seconds, by default. If the **kube controller** cannot read a node status value, it loses contact with that node after a configured period. The default behavior is:

1. The node controller on the control plane updates the node health to **Unhealthy** and marks the node **Ready** condition `Unknown`.
2. In response, the scheduler stops scheduling pods to that node.
3. The Node Lifecycle Controller adds a **node.kubernetes.io/unreachable** taint with a **NoExecute** effect to the node and schedules any pods on the node for eviction after five minutes, by default.

This behavior can cause problems if your network is prone to latency issues, especially if you have nodes at the network edge. In some cases, the Kubernetes Controller Manager might not receive an update from a healthy node due to network latency. The **Kubelet** evicts pods from the node even though the node is healthy.

To avoid this problem, you can use *worker latency profiles* to adjust the frequency that the **Kubelet** and the Kubernetes Controller Manager wait for status updates before taking action. These adjustments help to ensure that your cluster runs properly if network latency between the control plane and the worker nodes is not optimal.

These worker latency profiles contain three sets of parameters that are pre-defined with carefully tuned values to control the reaction of the cluster to increased latency. No need to experimentally find the best values manually.

You can configure worker latency profiles when installing a cluster or at any time you notice increased latency in your cluster network.

### Additional resources

- [Improving cluster stability in high latency environments using worker latency profiles](#)

## 9.1.5. Remote worker node strategies

If you use remote worker nodes, consider which objects to use to run your applications.

It is recommended to use daemon sets or static pods based on the behavior you want in the event of network issues or power loss. In addition, you can use Kubernetes zones and tolerations to control or avoid pod evictions if the control plane cannot reach remote worker nodes.

### Daemon sets

Daemon sets are the best approach to managing pods on remote worker nodes for the following reasons:

- Daemon sets do not typically need rescheduling behavior. If a node disconnects from the cluster, pods on the node can continue to run. OpenShift Container Platform does not change the state of daemon set pods, and leaves the pods in the state they last reported. For example, if a daemon set pod is in the **Running** state, when a node stops communicating, the pod keeps running and is assumed to be running by OpenShift Container Platform.

- Daemon set pods, by default, are created with **NoExecute** tolerations for the **node.kubernetes.io/unreachable** and **node.kubernetes.io/not-ready** taints with no **tolerationSeconds** value. These default values ensure that daemon set pods are never evicted if the control plane cannot reach a node. For example:

### Tolerations added to daemon set pods by default

tolerations:

- key: node.kubernetes.io/not-ready  
operator: Exists  
effect: NoExecute
- key: node.kubernetes.io/unreachable  
operator: Exists  
effect: NoExecute
- key: node.kubernetes.io/disk-pressure  
operator: Exists  
effect: NoSchedule
- key: node.kubernetes.io/memory-pressure  
operator: Exists  
effect: NoSchedule
- key: node.kubernetes.io/pid-pressure  
operator: Exists  
effect: NoSchedule
- key: node.kubernetes.io/unschedulable  
operator: Exists  
effect: NoSchedule

- Daemon sets can use labels to ensure that a workload runs on a matching worker node.
- You can use an OpenShift Container Platform service endpoint to load balance daemon set pods.

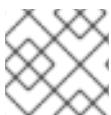


#### NOTE

Daemon sets do not schedule pods after a reboot of the node if OpenShift Container Platform cannot reach the node.

### Static pods

If you want pods restart if a node reboots, after a power loss for example, consider [static pods](#). The kubelet on a node automatically restarts static pods as node restarts.



#### NOTE

Static pods cannot use secrets and config maps.

### Kubernetes zones

[Kubernetes zones](#) can slow down the rate or, in some cases, completely stop pod evictions.

When the control plane cannot reach a node, the node controller, by default, applies **node.kubernetes.io/unreachable** taints and evicts pods at a rate of 0.1 nodes per second. However, in a cluster that uses Kubernetes zones, pod eviction behavior is altered.

If a zone is fully disrupted, where all nodes in the zone have a **Ready** condition that is **False** or **Unknown**, the control plane does not apply the **node.kubernetes.io/unreachable** taint to the nodes in that zone.

For partially disrupted zones, where more than 55% of the nodes have a **False** or **Unknown** condition, the pod eviction rate is reduced to 0.01 nodes per second. Nodes in smaller clusters, with fewer than 50 nodes, are not tainted. Your cluster must have more than three zones for these behavior to take effect.

You assign a node to a specific zone by applying the **topology.kubernetes.io/region** label in the node specification.

### Sample node labels for Kubernetes zones

```
kind: Node
apiVersion: v1
metadata:
  labels:
    topology.kubernetes.io/region=east
```

### KubeletConfig objects

You can adjust the amount of time that the kubelet checks the state of each node.

To set the interval that affects the timing of when the on-premise node controller marks nodes with the **Unhealthy** or **Unreachable** condition, create a **KubeletConfig** object that contains the **node-status-update-frequency** and **node-status-report-frequency** parameters.

The kubelet on each node determines the node status as defined by the **node-status-update-frequency** setting and reports that status to the cluster based on the **node-status-report-frequency** setting. By default, the kubelet determines the pod status every 10 seconds and reports the status every minute. However, if the node state changes, the kubelet reports the change to the cluster immediately. OpenShift Container Platform uses the **node-status-report-frequency** setting only when the Node Lease feature gate is enabled, which is the default state in OpenShift Container Platform clusters. If the Node Lease feature gate is disabled, the node reports its status based on the **node-status-update-frequency** setting.

### Example kubelet config

```
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: disable-cpu-units
spec:
  machineConfigPoolSelector:
    matchLabels:
      machineconfiguration.openshift.io/role: worker 1
  kubeletConfig:
    node-status-update-frequency: 2
      - "10s"
    node-status-report-frequency: 3
      - "1m"
```

**1** Specify the type of node type to which this **KubeletConfig** object applies using the label from the **MachineConfig** object.

**2** Specify the frequency that the kubelet checks the status of a node associated with this **MachineConfig** object. The default value is **10s**. If you change this default, the **node status**

**MachineConfig** object. The default value is **10s**. If you change this default, the **node-status-report-frequency** value is changed to the same value.

- 3 Specify the frequency that the kubelet reports the status of a node associated with this **MachineConfig** object. The default value is **1m**.

The **node-status-update-frequency** parameter works with the **node-monitor-grace-period** parameter.

- The **node-monitor-grace-period** parameter specifies how long OpenShift Container Platform waits after a node associated with a **MachineConfig** object is marked **Unhealthy** if the controller manager does not receive the node heartbeat. Workloads on the node continue to run after this time. If the remote worker node rejoins the cluster after **node-monitor-grace-period** expires, pods continue to run. New pods can be scheduled to that node. The **node-monitor-grace-period** interval is **40s**. The **node-status-update-frequency** value must be lower than the **node-monitor-grace-period** value.



#### NOTE

Modifying the **node-monitor-grace-period** parameter is not supported.

### Tolerations

You can use pod tolerations to mitigate the effects if the on-premise node controller adds a **node.kubernetes.io/unreachable** taint with a **NoExecute** effect to a node it cannot reach.

A taint with the **NoExecute** effect affects pods that are running on the node in the following ways:

- Pods that do not tolerate the taint are queued for eviction.
- Pods that tolerate the taint without specifying a **tolerationSeconds** value in their toleration specification remain bound forever.
- Pods that tolerate the taint with a specified **tolerationSeconds** value remain bound for the specified amount of time. After the time elapses, the pods are queued for eviction.



#### NOTE

Unless tolerations are explicitly set, Kubernetes automatically adds a toleration for **node.kubernetes.io/not-ready** and **node.kubernetes.io/unreachable** with **tolerationSeconds=300**, meaning that pods remain bound for 5 minutes if either of these taints is detected.

You can delay or avoid pod eviction by configuring pods tolerations with the **NoExecute** effect for the **node.kubernetes.io/unreachable** and **node.kubernetes.io/not-ready** taints.

### Example toleration in a pod spec

```
...
tolerations:
- key: "node.kubernetes.io/unreachable"
  operator: "Exists"
  effect: "NoExecute" 1
- key: "node.kubernetes.io/not-ready"
  operator: "Exists"
```

```
effect: "NoExecute" 2
tolerationSeconds: 600 3
...
```

- 1** The **NoExecute** effect without **tolerationSeconds** lets pods remain forever if the control plane cannot reach the node.
- 2** The **NoExecute** effect with **tolerationSeconds: 600** lets pods remain for 10 minutes if the control plane marks the node as **Unhealthy**.
- 3** You can specify your own **tolerationSeconds** value.

### Other types of OpenShift Container Platform objects

You can use replica sets, deployments, and replication controllers. The scheduler can reschedule these pods onto other nodes after the node is disconnected for five minutes. Rescheduling onto other nodes can be beneficial for some workloads, such as REST APIs, where an administrator can guarantee a specific number of pods are running and accessible.



#### NOTE

When working with remote worker nodes, rescheduling pods on different nodes might not be acceptable if remote worker nodes are intended to be reserved for specific functions.

[stateful sets](#) do not get restarted when there is an outage. The pods remain in the **terminating** state until the control plane can acknowledge that the pods are terminated.

To avoid scheduling a to a node that does not have access to the same type of persistent storage, OpenShift Container Platform cannot migrate pods that require persistent volumes to other zones in the case of network separation.

### Additional resources

- For more information on Daemonsets, see [DaemonSets](#).
- For more information on taints and tolerations, see [Controlling pod placement using node taints](#).
- For more information on configuring **KubeletConfig** objects, see [Creating a KubeletConfig CRD](#).
- For more information on replica sets, see [ReplicaSets](#).
- For more information on deployments, see [Deployments](#).
- For more information on replication controllers, see [Replication controllers](#).
- For more information on the controller manager, see [Kubernetes Controller Manager Operator](#).

## CHAPTER 10. WORKER NODES FOR SINGLE-NODE OPENSIFT CLUSTERS

### 10.1. ADDING WORKER NODES TO SINGLE-NODE OPENSIFT CLUSTERS

Single-node OpenShift clusters reduce the host prerequisites for deployment to a single host. This is useful for deployments in constrained environments or at the network edge. However, sometimes you need to add additional capacity to your cluster, for example, in telecommunications and network edge scenarios. In these scenarios, you can add worker nodes to the single-node cluster.



#### NOTE

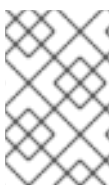
Unlike multi-node clusters, by default all ingress traffic is routed to the single control-plane node, even after adding additional worker nodes.

There are several ways that you can add worker nodes to a single-node cluster. You can add worker nodes to a cluster manually, using [Red Hat OpenShift Cluster Manager](#), or by using the Assisted Installer REST API directly.



#### IMPORTANT

Adding worker nodes does not expand the cluster control plane, and it does not provide high availability to your cluster. For single-node OpenShift clusters, high availability is handled by failing over to another site. When adding worker nodes to single-node OpenShift clusters, a tested maximum of two worker nodes is recommended. Exceeding the recommended number of worker nodes might result in lower overall performance, including cluster failure.



#### NOTE

To add worker nodes, you must have access to the OpenShift Cluster Manager. This method is not supported when using the Agent-based installer to install a cluster in a disconnected environment.

#### 10.1.1. Requirements for installing single-node OpenShift worker nodes

To install a single-node OpenShift worker node, you must address the following requirements:

- **Administration host:** You must have a computer to prepare the ISO and to monitor the installation.
- **Production-grade server:** Installing single-node OpenShift worker nodes requires a server with sufficient resources to run OpenShift Container Platform services and a production workload.

**Table 10.1. Minimum resource requirements**

| Profile | vCPU         | Memory     | Storage |
|---------|--------------|------------|---------|
| Minimum | 2 vCPU cores | 8GB of RAM | 100GB   |

**NOTE**

One vCPU is equivalent to one physical core when simultaneous multithreading (SMT), or hyperthreading, is not enabled. When enabled, use the following formula to calculate the corresponding ratio:

$$(\text{threads per core} \times \text{cores}) \times \text{sockets} = \text{vCPUs}$$

The server must have a Baseboard Management Controller (BMC) when booting with virtual media.

- **Networking:** The worker node server must have access to the internet or access to a local registry if it is not connected to a routable network. The worker node server must have a DHCP reservation or a static IP address and be able to access the single-node OpenShift cluster Kubernetes API, ingress route, and cluster node domain names. You must configure the DNS to resolve the IP address to each of the following fully qualified domain names (FQDN) for the single-node OpenShift cluster:

**Table 10.2. Required DNS records**

| Usage          | FQDN                                                    | Description                                                                                                                         |
|----------------|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Kubernetes API | <b>api.&lt;cluster_name&gt;.&lt;base_domain&gt;</b>     | Add a DNS A/AAAA or CNAME record. This record must be resolvable by clients external to the cluster.                                |
| Internal API   | <b>api-int.&lt;cluster_name&gt;.&lt;base_domain&gt;</b> | Add a DNS A/AAAA or CNAME record when creating the ISO manually. This record must be resolvable by nodes within the cluster.        |
| Ingress route  | <b>*.apps.&lt;cluster_name&gt;.&lt;base_domain&gt;</b>  | Add a wildcard DNS A/AAAA or CNAME record that targets the node. This record must be resolvable by clients external to the cluster. |

Without persistent IP addresses, communications between the **apiserver** and **etcd** might fail.

#### Additional resources

- [Minimum resource requirements for cluster installation](#)
- [Recommended practices for scaling the cluster](#)
- [User-provisioned DNS requirements](#)
- [Creating a bootable ISO image on a USB drive](#)
- [Booting from an ISO image served over HTTP using the Redfish API](#)
- [Deleting nodes from a cluster](#)

## 10.1.2. Adding worker nodes using the Assisted Installer and OpenShift Cluster Manager

You can add worker nodes to single-node OpenShift clusters that were created on [Red Hat OpenShift Cluster Manager](#) using the [Assisted Installer](#).



### IMPORTANT

Adding worker nodes to single-node OpenShift clusters is only supported for clusters running OpenShift Container Platform version 4.11 and up.

### Prerequisites

- Have access to a single-node OpenShift cluster installed using [Assisted Installer](#).
- Install the OpenShift CLI (**oc**).
- Log in as a user with **cluster-admin** privileges.
- Ensure that all the required DNS records exist for the cluster that you are adding the worker node to.

### Procedure

1. Log in to [OpenShift Cluster Manager](#) and click the single-node cluster that you want to add a worker node to.
2. Click **Add hosts**, and download the discovery ISO for the new worker node, adding SSH public key and configuring cluster-wide proxy settings as required.
3. Boot the target host using the discovery ISO, and wait for the host to be discovered in the console. After the host is discovered, start the installation.
4. As the installation proceeds, the installation generates pending certificate signing requests (CSRs) for the worker node. When prompted, approve the pending CSRs to complete the installation.

When the worker node is successfully installed, it is listed as a worker node in the cluster web console.



### IMPORTANT

New worker nodes will be encrypted using the same method as the original cluster.

### Additional resources

- [User-provisioned DNS requirements](#)
- [Approving the certificate signing requests for your machines](#)

## 10.1.3. Adding worker nodes using the Assisted Installer API

You can add worker nodes to single-node OpenShift clusters using the Assisted Installer REST API. Before you add worker nodes, you must log in to [OpenShift Cluster Manager](#) and authenticate against the API.



### 10.1.3.1. Authenticating against the Assisted Installer REST API

Before you can use the Assisted Installer REST API, you must authenticate against the API using a JSON web token (JWT) that you generate.

#### Prerequisites

- Log in to [OpenShift Cluster Manager](#) as a user with cluster creation privileges.
- Install `jq`.

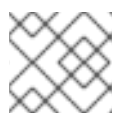
#### Procedure

1. Log in to [OpenShift Cluster Manager](#) and copy your API token.
2. Set the `$OFFLINE_TOKEN` variable using the copied API token by running the following command:

```
$ export OFFLINE_TOKEN=<copied_api_token>
```

3. Set the `$JWT_TOKEN` variable using the previously set `$OFFLINE_TOKEN` variable:

```
$ export JWT_TOKEN=$(
  curl \
  --silent \
  --header "Accept: application/json" \
  --header "Content-Type: application/x-www-form-urlencoded" \
  --data-urlencode "grant_type=refresh_token" \
  --data-urlencode "client_id=cloud-services" \
  --data-urlencode "refresh_token=${OFFLINE_TOKEN}" \
  "https://sso.redhat.com/auth/realms/redhat-external/protocol/openid-connect/token" \
  | jq --raw-output ".access_token"
)
```



#### NOTE

The JWT token is valid for 15 minutes only.

#### Verification

- Optional: Check that you can access the API by running the following command:

```
$ curl -s https://api.openshift.com/api/assisted-install/v2/component-versions -H
"Authorization: Bearer ${JWT_TOKEN}" | jq
```

#### Example output

```
{
  "release_tag": "v2.5.1",
  "versions":
  {
    "assisted-installer": "registry.redhat.io/rhai-tech-preview/assisted-installer-rhel8:v1.0.0-175",
    "assisted-installer-controller": "registry.redhat.io/rhai-tech-preview/assisted-installer-
```

```
reporter-rhel8:v1.0.0-223",
  "assisted-installer-service": "quay.io/app-sre/assisted-service:ac87f93",
  "discovery-agent": "registry.redhat.io/rhai-tech-preview/assisted-installer-agent-
rhel8:v1.0.0-156"
}
}
```

### 10.1.3.2. Adding worker nodes using the Assisted Installer REST API

You can add worker nodes to clusters using the Assisted Installer REST API.

#### Prerequisites

- Install the OpenShift Cluster Manager CLI (**ocm**).
- Log in to [OpenShift Cluster Manager](#) as a user with cluster creation privileges.
- Install **jq**.
- Ensure that all the required DNS records exist for the cluster that you are adding the worker node to.

#### Procedure

1. Authenticate against the Assisted Installer REST API and generate a JSON web token (JWT) for your session. The generated JWT token is valid for 15 minutes only.
2. Set the **\$API\_URL** variable by running the following command:

```
$ export API_URL=<api_url> 1
```

- 1** Replace **<api\_url>** with the Assisted Installer API URL, for example, <https://api.openshift.com>

3. Import the single-node OpenShift cluster by running the following commands:
  - a. Set the **\$OPENSHIFT\_CLUSTER\_ID** variable. Log in to the cluster and run the following command:

```
$ export OPENSHIFT_CLUSTER_ID=$(oc get clusterversion -o
jsonpath='{.items[].spec.clusterID}')
```

- b. Set the **\$CLUSTER\_REQUEST** variable that is used to import the cluster:

```
$ export CLUSTER_REQUEST=$(jq --null-input --arg openshift_cluster_id
"$OPENSHIFT_CLUSTER_ID" '{
  "api_vip_dnsname": "<api_vip>", 1
  "openshift_cluster_id": $openshift_cluster_id,
  "name": "<openshift_cluster_name>" 2
}')
```

- 1 Replace **<api\_vip>** with the hostname for the cluster's API server. This can be the DNS domain for the API server or the IP address of the single node which the worker node can reach. For example, **api.compute-1.example.com**.
- 2 Replace **<openshift\_cluster\_name>** with the plain text name for the cluster. The cluster name should match the cluster name that was set during the Day 1 cluster installation.

c. Import the cluster and set the **\$CLUSTER\_ID** variable. Run the following command:

```
$ CLUSTER_ID=$(curl "$API_URL/api/assisted-install/v2/clusters/import" -H
"Authorization: Bearer ${JWT_TOKEN}" -H 'accept: application/json' -H 'Content-Type:
application/json' \
-d "$CLUSTER_REQUEST" | tee /dev/stderr | jq -r '.id')
```

4. Generate the **InfraEnv** resource for the cluster and set the **\$INFRA\_ENV\_ID** variable by running the following commands:

- a. Download the pull secret file from Red Hat OpenShift Cluster Manager at [console.redhat.com](https://console.redhat.com).
- b. Set the **\$INFRA\_ENV\_REQUEST** variable:

```
export INFRA_ENV_REQUEST=$(jq --null-input \
--slurpfile pull_secret <path_to_pull_secret_file> \ 1
--arg ssh_pub_key "$(cat <path_to_ssh_pub_key>)" \ 2
--arg cluster_id "$CLUSTER_ID" '{
"name": "<infraenv_name>", 3
"pull_secret": $pull_secret[0] | tojson,
"cluster_id": $cluster_id,
"ssh_authorized_key": $ssh_pub_key,
"image_type": "<iso_image_type>" 4
}')
```

- 1 Replace **<path\_to\_pull\_secret\_file>** with the path to the local file containing the downloaded pull secret from Red Hat OpenShift Cluster Manager at [console.redhat.com](https://console.redhat.com).
- 2 Replace **<path\_to\_ssh\_pub\_key>** with the path to the public SSH key required to access the host. If you do not set this value, you cannot access the host while in discovery mode.
- 3 Replace **<infraenv\_name>** with the plain text name for the **InfraEnv** resource.
- 4 Replace **<iso\_image\_type>** with the ISO image type, either **full-iso** or **minimal-iso**.

c. Post the **\$INFRA\_ENV\_REQUEST** to the [/v2/infra-envs](https://api/assisted-install/v2/infra-envs) API and set the **\$INFRA\_ENV\_ID** variable:

```
$ INFRA_ENV_ID=$(curl "$API_URL/api/assisted-install/v2/infra-envs" -H "Authorization:
Bearer ${JWT_TOKEN}" -H 'accept: application/json' -H 'Content-Type: application/json'
-d "$INFRA_ENV_REQUEST" | tee /dev/stderr | jq -r '.id')
```

- Get the URL of the discovery ISO for the cluster worker node by running the following command:

```
$ curl -s "$API_URL/api/assisted-install/v2/infra-envs/$INFRA_ENV_ID" -H "Authorization: Bearer ${JWT_TOKEN}" | jq -r '.download_url'
```

### Example output

```
https://api.openshift.com/api/assisted-images/images/41b91e72-c33e-42ee-b80f-b5c5bbf6431a?arch=x86_64&image_token=eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJleHAiOiJlE2NTYwMjYzNzEsInN1YiI6IjQxYjIxZTcyLWZmM2UtNDJlZS1iODBmLWI1YzViYmY2NDMxYSJ9.1EX_VGaMNejMhrAvVRBS7PDPIQtboOoc8LtG8OukE1a4&type=minimal-iso&version=$VERSION
```

- Download the ISO:

```
$ curl -L -s '<iso_url>' --output rhcos-live-minimal.iso 1
```

- Replace **<iso\_url>** with the URL for the ISO from the previous step.

- Boot the new worker host from the downloaded **rhcos-live-minimal.iso**.
- Get the list of hosts in the cluster that are *not* installed. Keep running the following command until the new host shows up:

```
$ curl -s "$API_URL/api/assisted-install/v2/clusters/$CLUSTER_ID" -H "Authorization: Bearer ${JWT_TOKEN}" | jq -r '.hosts[] | select(.status != "installed").id'
```

### Example output

```
2294ba03-c264-4f11-ac08-2f1bb2f8c296
```

- Set the **\$HOST\_ID** variable for the new worker node, for example:

```
$ HOST_ID=<host_id> 1
```

- Replace **<host\_id>** with the host ID from the previous step.

- Check that the host is ready to install by running the following command:



### NOTE

Ensure that you copy the entire command including the complete **jq** expression.

```
$ curl -s $API_URL/api/assisted-install/v2/clusters/$CLUSTER_ID -H "Authorization: Bearer ${JWT_TOKEN}" | jq '
def host_name($host):
  if (.suggested_hostname // "") == "" then
    if (.inventory // "") == "" then
      "Unknown hostname, please wait"
```

```

    else
      .inventory | fromjson | .hostname
    end
  else
    .suggested_hostname
  end;

def is_notable($validation):
  ["failure", "pending", "error"] | any(. == $validation.status);

def notable_validations($validations_info):
  [
    $validations_info // "{}"
    | fromjson
    | to_entries[].value[]
    | select(is_notable(.))
  ];

{
  "Hosts validations": {
    "Hosts": [
      .hosts[]
      | select(.status != "installed")
      | {
        "id": .id,
        "name": host_name(.),
        "status": .status,
        "notable_validations": notable_validations(.validations_info)
      }
    ]
  },
  "Cluster validations info": {
    "notable_validations": notable_validations(.validations_info)
  }
}
'-r

```

### Example output

```

{
  "Hosts validations": {
    "Hosts": [
      {
        "id": "97ec378c-3568-460c-bc22-df54534ff08f",
        "name": "localhost.localdomain",
        "status": "insufficient",
        "notable_validations": [
          {
            "id": "ntp-synced",
            "status": "failure",
            "message": "Host couldn't synchronize with any NTP server"
          },
          {
            "id": "api-domain-name-resolved-correctly",
            "status": "error",
            "message": "Parse error for domain name resolutions result"
          }
        ]
      }
    ]
  }
}

```

```

    },
    {
      "id": "api-int-domain-name-resolved-correctly",
      "status": "error",
      "message": "Parse error for domain name resolutions result"
    },
    {
      "id": "apps-domain-name-resolved-correctly",
      "status": "error",
      "message": "Parse error for domain name resolutions result"
    }
  ]
}
]
},
"Cluster validations info": {
  "notable_validations": []
}
}

```

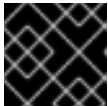
- When the previous command shows that the host is ready, start the installation using the `/v2/infra-envs/{infra_env_id}/hosts/{host_id}/actions/install` API by running the following command:

```

$ curl -X POST -s "$API_URL/api/assisted-install/v2/infra-
envs/$INFRA_ENV_ID/hosts/$HOST_ID/actions/install" -H "Authorization: Bearer
${JWT_TOKEN}"

```

- As the installation proceeds, the installation generates pending certificate signing requests (CSRs) for the worker node.



### IMPORTANT

You must approve the CSRs to complete the installation.

Keep running the following API call to monitor the cluster installation:

```

$ curl -s "$API_URL/api/assisted-install/v2/clusters/$CLUSTER_ID" -H "Authorization: Bearer
${JWT_TOKEN}" | jq '{
  "Cluster day-2 hosts":
    [
      .hosts[]
      | select(.status != "installed")
      | {id, requested_hostname, status, status_info, progress, status_updated_at,
updated_at, infra_env_id, cluster_id, created_at}
    ]
}'

```

### Example output

```

{
  "Cluster day-2 hosts": [
    {
      "id": "a1c52dde-3432-4f59-b2ae-0a530c851480",

```

```

    "requested_hostname": "control-plane-1",
    "status": "added-to-existing-cluster",
    "status_info": "Host has rebooted and no further updates will be posted. Please check
console for progress and to possibly approve pending CSRs",
    "progress": {
      "current_stage": "Done",
      "installation_percentage": 100,
      "stage_started_at": "2022-07-08T10:56:20.476Z",
      "stage_updated_at": "2022-07-08T10:56:20.476Z"
    },
    "status_updated_at": "2022-07-08T10:56:20.476Z",
    "updated_at": "2022-07-08T10:57:15.306369Z",
    "infra_env_id": "b74ec0c3-d5b5-4717-a866-5b6854791bd3",
    "cluster_id": "8f721322-419d-4eed-aa5b-61b50ea586ae",
    "created_at": "2022-07-06T22:54:57.161614Z"
  }
]
}

```

- Optional: Run the following command to see all the events for the cluster:

```

$ curl -s "$API_URL/api/assisted-install/v2/events?cluster_id=$CLUSTER_ID" -H
"Authorization: Bearer ${JWT_TOKEN}" | jq -c '[] | {severity, message, event_time, host_id}'

```

### Example output

```

{"severity":"info","message":"Host compute-0: updated status from insufficient to known (Host
is ready to be installed)","event_time":"2022-07-08T11:21:46.346Z","host_id":"9d7b3b44-
1125-4ad0-9b14-76550087b445"}
{"severity":"info","message":"Host compute-0: updated status from known to installing
(Installation is in progress)","event_time":"2022-07-08T11:28:28.647Z","host_id":"9d7b3b44-
1125-4ad0-9b14-76550087b445"}
{"severity":"info","message":"Host compute-0: updated status from installing to installing-in-
progress (Starting installation)","event_time":"2022-07-
08T11:28:52.068Z","host_id":"9d7b3b44-1125-4ad0-9b14-76550087b445"}
{"severity":"info","message":"Uploaded logs for host compute-0 cluster 8f721322-419d-4eed-
aa5b-61b50ea586ae","event_time":"2022-07-08T11:29:47.802Z","host_id":"9d7b3b44-1125-
4ad0-9b14-76550087b445"}
{"severity":"info","message":"Host compute-0: updated status from installing-in-progress to
added-to-existing-cluster (Host has rebooted and no further updates will be posted. Please
check console for progress and to possibly approve pending CSRs)","event_time":"2022-07-
08T11:29:48.259Z","host_id":"9d7b3b44-1125-4ad0-9b14-76550087b445"}
{"severity":"info","message":"Host: compute-0, reached installation stage
Rebooting","event_time":"2022-07-08T11:29:48.261Z","host_id":"9d7b3b44-1125-4ad0-9b14-
76550087b445"}

```

- Log in to the cluster and approve the pending CSRs to complete the installation.

### Verification

- Check that the new worker node was successfully added to the cluster with a status of **Ready**:

```

$ oc get nodes

```

## Example output

| NAME                        | STATUS | ROLES         | AGE | VERSION |
|-----------------------------|--------|---------------|-----|---------|
| control-plane-1.example.com | Ready  | master,worker | 56m | v1.30.3 |
| compute-1.example.com       | Ready  | worker        | 11m | v1.30.3 |

## Additional resources

- [User-provisioned DNS requirements](#)
- [Approving the certificate signing requests for your machines](#)

## 10.1.4. Adding worker nodes to single-node OpenShift clusters manually

You can add a worker node to a single-node OpenShift cluster manually by booting the worker node from Red Hat Enterprise Linux CoreOS (RHCOS) ISO and by using the cluster **worker.ign** file to join the new worker node to the cluster.

### Prerequisites

- Install a single-node OpenShift cluster on bare metal.
- Install the OpenShift CLI (**oc**).
- Log in as a user with **cluster-admin** privileges.
- Ensure that all the required DNS records exist for the cluster that you are adding the worker node to.

### Procedure

1. Set the OpenShift Container Platform version:

```
$ OCP_VERSION=<ocp_version> 1
```

- 1 Replace **<ocp\_version>** with the current version, for example, **latest-4.17**

2. Set the host architecture:

```
$ ARCH=<architecture> 1
```

- 1 Replace **<architecture>** with the target host architecture, for example, **aarch64** or **x86\_64**.

3. Get the **worker.ign** data from the running single-node cluster by running the following command:

```
$ oc extract -n openshift-machine-api secret/worker-user-data-managed --keys=userData --to=- > worker.ign
```

4. Host the **worker.ign** file on a web server accessible from your network.



5. Download the OpenShift Container Platform installer and make it available for use by running the following commands:

```
$ curl -k https://mirror.openshift.com/pub/openshift-
v4/clients/ocp/$OCP_VERSION/openshift-install-linux.tar.gz > openshift-install-linux.tar.gz
```

```
$ tar zxvf openshift-install-linux.tar.gz
```

```
$ chmod +x openshift-install
```

6. Retrieve the RHCOS ISO URL:

```
$ ISO_URL=$(./openshift-install coreos print-stream-json | grep location | grep $ARCH | grep
iso | cut -d\" -f4)
```

7. Download the RHCOS ISO:

```
$ curl -L $ISO_URL -o rhcos-live.iso
```

8. Use the RHCOS ISO and the hosted **worker.ign** file to install the worker node:

- a. Boot the target host with the RHCOS ISO and your preferred method of installation.
- b. When the target host has booted from the RHCOS ISO, open a console on the target host.
- c. If your local network does not have DHCP enabled, you need to create an ignition file with the new hostname and configure the worker node static IP address before running the RHCOS installation. Perform the following steps:
  - i. Configure the worker host network connection with a static IP. Run the following command on the target host console:

```
$ nmcli con mod <network_interface> ipv4.method manual /
ipv4.addresses <static_ip> ipv4.gateway <network_gateway> ipv4.dns <dns_server>
/
802-3-ethernet.mtu 9000
```

where:

**<static\_ip>**

Is the host static IP address and CIDR, for example, **10.1.101.50/24**

**<network\_gateway>**

Is the network gateway, for example, **10.1.101.1**

- ii. Activate the modified network interface:

```
$ nmcli con up <network_interface>
```

- iii. Create a new ignition file **new-worker.ign** that includes a reference to the original **worker.ign** and an additional instruction that the **coreos-installer** program uses to populate the **/etc/hostname** file on the new worker host. For example:

```
{
```

```

"ignition":{
  "version":"3.2.0",
  "config":{
    "merge":[
      {
        "source":"<hosted_worker_ign_file>" ❶
      }
    ]
  },
  "storage":{
    "files":[
      {
        "path":"/etc/hostname",
        "contents":{
          "source":"data:,<new_fqdn>" ❷
        },
        "mode":420,
        "overwrite":true,
        "path":"/etc/hostname"
      }
    ]
  }
}

```

- ❶ **<hosted\_worker\_ign\_file>** is the locally accessible URL for the original **worker.ign** file. For example, <http://webserver.example.com/worker.ign>
- ❷ **<new\_fqdn>** is the new FQDN that you set for the worker node. For example, **new-worker.example.com**.

- iv. Host the **new-worker.ign** file on a web server accessible from your network.
- v. Run the following **coreos-installer** command, passing in the **ignition-url** and hard disk details:

```
$ sudo coreos-installer install --copy-network /
--ignition-url=<new_worker_ign_file> <hard_disk> --insecure-ignition
```

where:

**<new\_worker\_ign\_file>**

is the locally accessible URL for the hosted **new-worker.ign** file, for example, <http://webserver.example.com/new-worker.ign>

**<hard\_disk>**

is the hard disk where you install RHCOS, for example, **/dev/sda**

- d. For networks that have DHCP enabled, you do not need to set a static IP. Run the following **coreos-installer** command from the target host console to install the system:

```
$ coreos-installer install --ignition-url=<hosted_worker_ign_file> <hard_disk>
```

- e. To manually enable DHCP, apply the following **NMStateConfig** CR to the single-node OpenShift cluster:

```

apiVersion: agent-install.openshift.io/v1
kind: NMStateConfig
metadata:
  name: nmstateconfig-dhcp
  namespace: example-sno
  labels:
    nmstate_config_cluster_name: <nmstate_config_cluster_label>
spec:
  config:
    interfaces:
      - name: eth0
        type: ethernet
        state: up
        ipv4:
          enabled: true
          dhcp: true
        ipv6:
          enabled: false
    interfaces:
      - name: "eth0"
        macAddress: "AA:BB:CC:DD:EE:11"

```



### IMPORTANT

The **NMStateConfig** CR is required for successful deployments of worker nodes with static IP addresses and for adding a worker node with a dynamic IP address if the single-node OpenShift was deployed with a static IP address. The cluster network DHCP does not automatically set these network settings for the new worker node.

9. As the installation proceeds, the installation generates pending certificate signing requests (CSRs) for the worker node. When prompted, approve the pending CSRs to complete the installation.
10. When the install is complete, reboot the host. The host joins the cluster as a new worker node.

### Verification

- Check that the new worker node was successfully added to the cluster with a status of **Ready**:

```
$ oc get nodes
```

### Example output

| NAME                        | STATUS | ROLES         | AGE | VERSION |
|-----------------------------|--------|---------------|-----|---------|
| control-plane-1.example.com | Ready  | master,worker | 56m | v1.30.3 |
| compute-1.example.com       | Ready  | worker        | 11m | v1.30.3 |

### Additional resources

- [User-provisioned DNS requirements](#)

- [Approving the certificate signing requests for your machines](#)

### 10.1.5. Approving the certificate signing requests for your machines

When you add machines to a cluster, two pending certificate signing requests (CSRs) are generated for each machine that you added. You must confirm that these CSRs are approved or, if necessary, approve them yourself. The client requests must be approved first, followed by the server requests.

#### Prerequisites

- You added machines to your cluster.

#### Procedure

1. Confirm that the cluster recognizes the machines:

```
$ oc get nodes
```

#### Example output

```
NAME      STATUS    ROLES    AGE   VERSION
master-0  Ready    master   63m   v1.30.3
master-1  Ready    master   63m   v1.30.3
master-2  Ready    master   64m   v1.30.3
```

The output lists all of the machines that you created.



#### NOTE

The preceding output might not include the compute nodes, also known as worker nodes, until some CSRs are approved.

2. Review the pending CSRs and ensure that you see the client requests with the **Pending** or **Approved** status for each machine that you added to the cluster:

```
$ oc get csr
```

#### Example output

```
NAME      AGE   REQUESTOR                                     CONDITION
csr-8b2br  15m   system:serviceaccount:openshift-machine-config-operator:node-
bootstrapper  Pending
csr-8vnps  15m   system:serviceaccount:openshift-machine-config-operator:node-
bootstrapper  Pending
...
```

In this example, two machines are joining the cluster. You might see more approved CSRs in the list.

3. If the CSRs were not approved, after all of the pending CSRs for the machines you added are in **Pending** status, approve the CSRs for your cluster machines:

**NOTE**

Because the CSRs rotate automatically, approve your CSRs within an hour of adding the machines to the cluster. If you do not approve them within an hour, the certificates will rotate, and more than two certificates will be present for each node. You must approve all of these certificates. After the client CSR is approved, the Kubelet creates a secondary CSR for the serving certificate, which requires manual approval. Then, subsequent serving certificate renewal requests are automatically approved by the **machine-approver** if the Kubelet requests a new certificate with identical parameters.

**NOTE**

For clusters running on platforms that are not machine API enabled, such as bare metal and other user-provisioned infrastructure, you must implement a method of automatically approving the kubelet serving certificate requests (CSRs). If a request is not approved, then the **oc exec**, **oc rsh**, and **oc logs** commands cannot succeed, because a serving certificate is required when the API server connects to the kubelet. Any operation that contacts the Kubelet endpoint requires this certificate approval to be in place. The method must watch for new CSRs, confirm that the CSR was submitted by the **node-bootstrapper** service account in the **system:node** or **system:admin** groups, and confirm the identity of the node.

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

- 1** **<csr\_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{"\n"}\n{{end}}{{end}}' | xargs --no-run-if-empty oc adm certificate approve
```

**NOTE**

Some Operators might not become available until some CSRs are approved.

4. Now that your client requests are approved, you must review the server requests for each machine that you added to the cluster:

```
$ oc get csr
```

**Example output**

```
NAME      AGE   REQUESTOR                                     CONDITION
csr-bfd72 5m26s system:node:ip-10-0-50-126.us-east-2.compute.internal
Pending
csr-c57lv 5m26s system:node:ip-10-0-95-157.us-east-2.compute.internal
Pending
...
```

5. If the remaining CSRs are not approved, and are in the **Pending** status, approve the CSRs for your cluster machines:

- To approve them individually, run the following command for each valid CSR:

```
$ oc adm certificate approve <csr_name> 1
```

**1** **<csr\_name>** is the name of a CSR from the list of current CSRs.

- To approve all pending CSRs, run the following command:

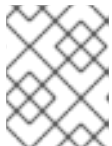
```
$ oc get csr -o go-template='{{range .items}}{{if not .status}}{{.metadata.name}}{\n"}\n{{end}}' | xargs oc adm certificate approve
```

6. After all client and server CSRs have been approved, the machines have the **Ready** status. Verify this by running the following command:

```
$ oc get nodes
```

### Example output

```
NAME      STATUS    ROLES    AGE    VERSION
master-0  Ready    master   73m    v1.30.3
master-1  Ready    master   73m    v1.30.3
master-2  Ready    master   74m    v1.30.3
worker-0  Ready    worker   11m    v1.30.3
worker-1  Ready    worker   11m    v1.30.3
```



### NOTE

It can take a few minutes after approval of the server CSRs for the machines to transition to the **Ready** status.

### Additional information

- [Certificate Signing Requests](#)

## CHAPTER 11. NODE METRICS DASHBOARD

The node metrics dashboard is a visual analytics dashboard that helps you identify potential pod scaling issues.

### 11.1. ABOUT THE NODE METRICS DASHBOARD

The node metrics dashboard enables administrative and support team members to monitor metrics related to pod scaling, including scaling limits used to diagnose and troubleshoot scaling issues. Particularly, you can use the visual analytics displayed through the dashboard to monitor workload distributions across nodes. Insights gained from these analytics help you determine the health of your CRI-O and Kubelet system components as well as identify potential sources of excessive or imbalanced resource consumption and system instability.

The dashboard displays visual analytics widgets organized into the following categories:

#### Critical

Includes visualizations that can help you identify node issues that could result in system instability and inefficiency

#### Outliers

Includes histograms that visualize processes with runtime durations that fall outside of the 95th percentile

#### Average durations

Helps you track change in the time that system components take to process operations

#### Number of operations

Displays visualizations that help you identify changes in the number of operations being run, which in turn helps you determine the load balance and efficiency of your system

### 11.2. ACCESSING THE NODE METRICS DASHBOARD

You can access the node metrics dashboard from the **Administrator** perspective.

#### Procedure

1. Expand the **Observe** menu option and select **Dashboards**.
2. Under the **Dashboard** filter, select **Node cluster**.



#### NOTE

If no data appears in the visualizations under the **Critical** category, no critical anomalies were detected. The dashboard is working as intended.

### 11.3. IDENTIFY METRICS FOR INDICATING OPTIMAL NODE RESOURCE USAGE

The node metrics dashboard is organized into four categories: **Critical**, **Outliers**, **Average durations**, and **Number of Operations**. The metrics in the **Critical** category help you indicate optimal node resource usage. These metrics include:

- Top 3 containers with the most OOM kills in the last day

- Failure rate for image pulls in the last hour
- Nodes with system reserved memory utilization > 80%
- Nodes with Kubelet system reserved memory utilization > 50%
- Nodes with CRI-O system reserved memory utilization > 50%
- Nodes with system reserved CPU utilization > 80%
- Nodes with Kubelet system reserved CPU utilization > 50%
- Nodes with CRI-O system reserved CPU utilization > 50%

### 11.3.1. Top 3 containers with the most OOM kills in the last day

The **Top 3 containers with the most OOM kills in the last day** query fetches details regarding the top three containers that have experienced the most Out-Of-Memory (OOM) kills in the previous day.

#### Example default query

```
topk(3, sum(increase(container_runtime_crio_containers_oom_count_total[1d])) by (name))
```

OOM kills force the system to terminate some processes due to low memory. Frequent OOM kills can hinder the functionality of the node and even the entire Kubernetes ecosystem. Containers experiencing frequent OOM kills might be consuming more memory than they should, which causes system instability.

Use this metric to identify containers that are experiencing frequent OOM kills and investigate why these containers are consuming an excessive amount of memory. Adjust the resource allocation if necessary and consider resizing the containers based on their memory usage. You can also review the metrics under the **Outliers**, **Average durations**, and **Number of operations** categories to gain further insights into the health and stability of your nodes.

### 11.3.2. Failure rate for image pulls in the last hour

The **Failure rate for image pulls in the last hour** query divides the total number of failed image pulls by the sum of successful and failed image pulls to provide a ratio of failures.

#### Example default query

```
rate(container_runtime_crio_image_pulls_failure_total[1h]) /  
(rate(container_runtime_crio_image_pulls_success_total[1h]) +  
rate(container_runtime_crio_image_pulls_failure_total[1h]))
```

Understanding the failure rate of image pulls is crucial for maintaining the health of the node. A high failure rate might indicate networking issues, storage problems, misconfigurations, or other issues that could disrupt pod density and the deployment of new containers.

If the outcome of this query is high, investigate possible causes such as network connections, the availability of remote repositories, node storage, and the accuracy of image references. You can also review the metrics under the **Outliers**, **Average durations**, and **Number of operations** categories to gain further insights.



### 11.3.3. Nodes with system reserved memory utilization > 80%

The **Nodes with system reserved memory utilization > 80%** query calculates the percentage of system reserved memory that is utilized for each node. The calculation divides the total resident set size (RSS) by the total memory capacity of the node subtracted from the allocatable memory. RSS is the portion of the system's memory occupied by a process that is held in main memory (RAM). Nodes are flagged if their resulting value equals or exceeds an 80% threshold.

#### Example default query

```
sum by (node) (container_memory_rss{id="/system.slice"}) / sum by (node)
(kube_node_status_capacity{resource="memory"} -
kube_node_status_allocatable{resource="memory"}) * 100 >= 80
```

System reserved memory is crucial for a Kubernetes node as it is utilized to run system daemons and Kubernetes system daemons. System reserved memory utilization that exceeds 80% indicates that the system and Kubernetes daemons are consuming too much memory and can suggest node instability that could affect the performance of running pods. Excessive memory consumption can cause Out-of-Memory (OOM) killers that can terminate critical system processes to free up memory.

If a node is flagged by this metric, identify which system or Kubernetes processes are consuming excessive memory and take appropriate actions to mitigate the situation. These actions may include scaling back non-critical processes, optimizing program configurations to reduce memory usage, or upgrading node systems to hardware with greater memory capacity. You can also review the metrics under the **Outliers**, **Average durations**, and **Number of operations** categories to gain further insights into node performance.

### 11.3.4. Nodes with Kubelet system reserved memory utilization > 50%

The **Nodes with Kubelet system reserved memory utilization > 50%** query indicates nodes where the Kubelet's system reserved memory utilization exceeds 50%. The query examines the memory that the Kubelet process itself is consuming on a node.

#### Example default query

```
sum by (node) (container_memory_rss{id="/system.slice/kubelet.service"}) / sum by (node)
(kube_node_status_capacity{resource="memory"} -
kube_node_status_allocatable{resource="memory"}) * 100 >= 50
```

This query helps you identify any possible memory pressure situations in your nodes that could affect the stability and efficiency of node operations. Kubelet memory utilization that consistently exceeds 50% of the system reserved memory, indicate that the system reserved settings are not configured properly and that there is a high risk of the node becoming unstable.

If this metric is highlighted, review your configuration policy and consider adjusting the system reserved settings or the resource limits settings for the Kubelet. Additionally, if your Kubelet memory utilization consistently exceeds half of your total reserved system memory, examine metrics under the **Outliers**, **Average durations**, and **Number of operations** categories to gain further insights for more precise diagnostics.

### 11.3.5. Nodes with CRI-O system reserved memory utilization > 50%

The **Nodes with CRI-O system reserved memory utilization > 50%** query calculates all nodes where the percentage of used memory reserved for the CRI-O system is greater than or equal to 50%. In this

case, memory usage is defined by the resident set size (RSS), which is the portion of the CRI-O system's memory held in RAM.

### Example default query

```
sum by (node) (container_memory_rss{id="/system.slice/crio.service"}) / sum by (node)
(kube_node_status_capacity{resource="memory"} -
kube_node_status_allocatable{resource="memory"}) * 100 >= 50
```

This query helps you monitor the status of memory reserved for the CRI-O system on each node. High utilization could indicate a lack of available resources and potential performance issues. If the memory reserved for the CRI-O system exceeds the advised limit of 50%, it indicates that half of the system reserved memory is being used by CRI-O on a node.

Check memory allocation and usage and assess whether memory resources need to be shifted or increased to prevent possible node instability. You can also examine the metrics under the **Outliers**, **Average durations**, and **Number of operations** categories to gain further insights.

### 11.3.6. Nodes with System Reserved CPU Utilization > 80%

The **Nodes with system reserved CPU utilization > 80%** query identifies nodes where the system-reserved CPU utilization is more than 80%. The query focuses on the system-reserved capacity to calculate the rate of CPU usage in the last 5 minutes and compares that to the CPU resources available on the nodes. If the ratio exceeds 80%, the node's result is displayed in the metric.

### Example default query

```
sum by (node) (rate(container_cpu_usage_seconds_total{id="/system.slice"}[5m]) * 100) / sum by
(node) (kube_node_status_capacity{resource="cpu"} -
kube_node_status_allocatable{resource="cpu"}) >= 80
```

This query indicates a critical level of system-reserved CPU usage, which can lead to resource exhaustion. High system-reserved CPU usage can result in the inability of the system processes (including the Kubelet and CRI-O) to adequately manage resources on the node. This query can indicate excessive system processes or misconfigured CPU allocation.

Potential corrective measures include rebalancing workloads to other nodes or increasing the CPU resources allocated to the nodes. Investigate the cause of the high system CPU utilization and review the corresponding metrics in the **Outliers**, **Average durations**, and **Number of operations** categories for additional insights into the node's behavior.

### 11.3.7. Nodes with Kubelet system reserved CPU utilization > 50%

The **Nodes with Kubelet system reserved CPU utilization > 50%** query calculates the percentage of the CPU that the Kubelet system is currently using from system reserved.

### Example default query

```
sum by (node) (rate(container_cpu_usage_seconds_total{id="/system.slice/kubelet.service"}[5m]) *
100) / sum by (node) (kube_node_status_capacity{resource="cpu"} -
kube_node_status_allocatable{resource="cpu"}) >= 50
```

The Kubelet uses the system reserved CPU for its own operations and for running critical system services. For the node's health, it is important to ensure that system reserve CPU usage does not

exceed the 50% threshold. Exceeding this limit could indicate heavy utilization or load on the Kubelet, which affects node stability and potentially the performance of the entire Kubernetes cluster.

If any node is displayed in this metric, the Kubelet and the system overall are under heavy load. You can reduce overload on a particular node by balancing the load across other nodes in the cluster. Check other query metrics under the **Outliers**, **Average durations**, and **Number of operations** categories to gain further insights and take necessary corrective action.

### 11.3.8. Nodes with CRI-O system reserved CPU utilization > 50%

The **Nodes with CRI-O system reserved CPU utilization > 50%** query identifies nodes where the CRI-O system reserved CPU utilization has exceeded 50% in the last 5 minutes. The query monitors CPU resource consumption by CRI-O, your container runtime, on a per-node basis.

#### Example default query

```
sum by (node) (rate(container_cpu_usage_seconds_total{id="/system.slice/crio.service"}[5m]) * 100)
/ sum by (node) (kube_node_status_capacity{resource="cpu"} -
kube_node_status_allocatable{resource="cpu"}) >= 50
```

This query allows for quick identification of abnormal start times that could negatively impact pod performance. If this query returns a high value, your pod start times are slower than usual, which suggests potential issues with the kubelet, pod configuration, or resources.

Investigate further by checking your pod configurations and allocated resources. Make sure that they align with your system capabilities. If you still see high start times, explore metrics panels from other categories on the dashboard to determine the state of your system components.

## 11.4. CUSTOMIZING DASHBOARD QUERIES

You can customize the default queries used to build the node metrics dashboard.

#### Procedure

1. Choose a metric and click **Inspect** to navigate into the data. This page displays the metric in detail, including an expanded visualization of the results of the query, the Prometheus query used to analyze the data, and the data subset used in the query.
2. Make any required changes to the query parameters.
3. Optional: Click **Add query** to run additional queries against the data.
4. Click **Run query** to rerun the query using your specified parameters.

## CHAPTER 12. MANAGE SECURE SIGNATURES WITH SIGSTORE

You can use the sigstore project with OpenShift Container Platform to improve supply chain security.

### 12.1. ABOUT THE SIGSTORE PROJECT

The sigstore project enables developers to sign-off on what they build and administrators to verify signatures and monitor workflows at scale. With the sigstore project, signatures can be stored in the same registry as the build images. A second server is not needed. The identity piece of a signature is tied to the OpenID Connect (OIDC) identity through the Fulcio certificate authority, which simplifies the signature process by allowing key-less signing. Additionally, sigstore includes Rekor, which records signature metadata to an immutable, tamper-resistant ledger.